Mid-Atlantic Regional Agronomist Quarterly Newsletter

March 2008

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What Is a Falling Number and What Does It Mean About Your Wheat?

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A particularly wet harvest season in some areas in 2006 has drawn attention to the topic of pre-harvest sprouting in the mid-Atlantic region. According to the U.S. Wheat Associates report, "Relatively high damaged kernel values and low falling numbers in the East reflect the difficult harvest conditions there, while very good values were recorded in other states." Last year's flour data reflected a decreased falling number average. In 2006 the falling number average for east coast wheat was 260 seconds a 25% decrease from the five year average of 347 seconds. Figure 1 shows wheat falling number ranges for the eastern US and the Gulf from 2006.

Figure 1. Wheat falling number values for the 2006 crop. US Wheat Associates Report.
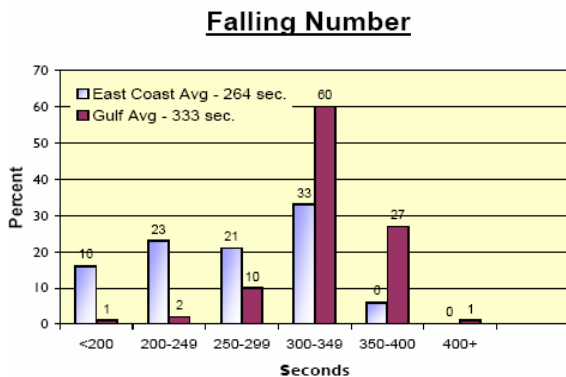
A falling number test measures the level of alpha amylase activity that has occurred within a grain sample. Released as seeds sprout, alpha amylase is an enzyme that degrades starches within the seed, greatly reducing flour quality. Falling number tests are conducted by creating a slurry from ground wheat flour and water. Sound grain (high falling number) produces a thick slurry because the starches are still in tact. Sprout damaged grain will result in a flour/water mixture that is "thin" or non-viscous because the starches have began breaking down due to the alpha amylase activity. The time for a plunger to move through the slurry to the bottom of a test tube is measured. The faster the plunger reaches the bottom of the test tube, the lower the viscosity of the mixture (thinner) and the higher the alpha-amylase activity or sprout damage.

In general, values below 300 seconds are indicative of poor quality for milling and baking purposes. Sprout damaged grain can affect mixability, crumb strength, sliceablity, and volume. Wheat that does not meet the minimum falling number standard is unsuitable for milling and is usually sold to the livestock feed market. Flour quality wheat generally receives a premium of $0.40 or more per bushel over feed wheat.

Earlier studies have demonstrated that pre-harvest sprouting is partially controlled by genetics. Lines with white seed coat color are generally more susceptible to sprouting than those with red seed coats. We intend to evaluate current commercial and experimental wheat lines available in Virginia for their resistance to sprouting in the coming year.

Environmental conditions both before and after seed maturity influence the rate of pre-harvest sprouting. In general, the more wetting and drying cycles the seed experiences, the more likely it is to break dormancy and sprout. This type of weathering also decreases grain test weight which is another important component of wheat quality evaluation.

To minimize pre-harvest sprouting and test weight losses, harvest and dry wheat the first time it reaches 20 percent moisture or the first time it reaches 15 percent moisture if drying is not possible. Make sure the combine and all other critical equipment including hauling capacity are "ready to roll." Try not to let other steps in the harvesting chain limit the combine capacity per day. Set the combine properly and modify the cylinder speed and/or concave clearance as harvest conditions change during the day. Timely harvest is absolutely critical if milling quality wheat is to be produced.

Wheat Nutrition—Secondary Macronutrients and Micronutrients

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Although growers are concerned mostly with nitrogen (N) fertilization on wheat and barley, other nutrients sometimes can limit yield potential especially on sandy Coastal Plain soils in the mid-Atlantic region. Delmarva often has fields that show deficiency symptoms or poor growth rates following spring N applications. The discussion that follows highlights some cases of nutrient deficiency that have been documented with soil and tissue testing and points out where and when the grower can expect problems. Fertilizer choice, rate, and method of application are also discussed.

Sulfur (S)

In past years, quite a few small grain fields located on sandy soils in both Delaware and Maryland have shown large areas of yellowed, stunted plants for both wheat and barley.

Photo 1. Field view of barley showing sulfur (S) deficiency (tissue test indicated 0.11 percent S and >5 percent nitrogen) on very sandy soil that had been fertilized with 20+ pounds per acre of S that likely was leached by heavy spring rains (Photo by R. Taylor).

Usually symptoms are noticed or appear shortly after spring fertilization with N. In many cases, deficiency of either S or Mg has been confirmed with both tissue and soil samples. Examples of fields showing classic deficiency symptoms for S are shown in photos 1 to 4.

The symptoms include stunting of plants, general yellowing or chlorosis especially of the new growth (remember that S is immobile in the plant causing symptoms first to occur on new growth but when deficiencies are severe symptoms can involve the whole plant), delayed head emergence, delayed maturity, and poor root development. In the barley shown in Photos 1 to 4, the root system of the affected plants was limited to the upper 2 to 4 inches and the soil type was loamy sand. Rooting depth was limited in part by soil acidity and in part by winter conditions and heavy spring rainfall that leached applied S rapidly out of the rooting zone.

With S deficiency, the symptoms often can be attributed to a high tissue N concentration. With inadequate S uptake, plants are unable to synthesize S-containing amino acids, limiting the ability of the plant to make the proteins and enzymes that do much of the work producing yield. In essence, a high tissue N content can worsen S deficiency.

Why does S deficiency sometimes occur? A severe winter or very cold spring can limit root development. If excessive rainfall occurs on sandy soils, S can leach below the crop rooting zone. Compaction issues that limit rooting depth also impact S availability. Many of the fields that have shown S deficiency in the past were low in soil organic matter (SOM) that supplies some S. Cold spring conditions can inhibit SOM mineralization reducing S availability. In the above case (Photo 1 to 4), S was applied along with N but heavy spring rainfall likely leached much of the S below the shallow rooting depth of the crop.

Photo 2. Barley showing sulfur (S) deficiency symptoms of stunted plants with generally yellowing but beginning with newly emerged leaves (tissue test indicated 0.11 percent S and >5 percent nitrogen) on very sandy soil that had been fertilized with 20+ pounds per acre of S that likely was leached by heavy spring rains (Photo by R. Taylor).

Photo 3. Barley showing sulfur (S) deficiency symptom of severe stunting (tissue test indicated 0.11 percent S and >5 percent nitrogen) on very sandy soil that had been fertilized with 20+ pounds per acre of S that likely was leached by heavy spring rains (Photo by R. Taylor).

To alleviate the deficiency, sulfur should be applied as either a foliar spray for quick relief of the symptoms or as a soil application. Several products have been used including Epsom salts (magnesium sulfate), Sul-PoMag or K-Mag [Sulfate of potash-magnesia ($K_2SO4-2MgSO_4$), containing about 22 percent K_2O (potash), 11 percent magnesium (Mg) and 22 percent S], and ammonium sulfate. Epsom salts does have limited solubility in water and ammonium sulfate can cause some plant burn if applied at high rates. All of the above products can be used to provide the needed nutrients. Each product should be evaluated on a cost per pound of nutrient basis. Potash applied with

Sul-PoMag or K-Mag can substitute for the potash recommended for a double-cropped soybean crop that is planted immediately following harvest of the small grain crop.

Photo 4. Barley showing sulfur (S) deficiency symptom of stunting and general chlorosis or yellowing (tissue test indicated 0.11 percent S and >5 percent nitrogen) on very sandy soil that had been fertilized with 20+ pounds per acre of S that likely was leached by heavy spring rains (Photo by R. Taylor).

Magnesium (Mg)

Photo 5. Barley showing sulfur (S) and magnesium (Mg) deficiency symptom of interveinal chlorosis or yellowing (tissue test confirmed S and Mg deficiencies) on a loamy sand soil near Laurel, DE (Photo by R. Taylor).

Other very sandy fields have shown both S and Mg deficiency symptoms in both barley (Photo 5 and 6) and wheat (Photo 7 and 8). In some cases, the soil pH was about 6.0. Typically, Mg deficiency is found on soils with a pH of less than about 5.2 in our area. A pH of 6.0 would indicate that both calcium (Ca) and Mg soil test levels were adequate. Why was Mg deficiency showing up where you would expect adequate soil test level of Mg? Grasses, which both wheat and barley are, often are unable to absorb adequate Mg in cool, wet springs. This situation most often is seen in forage grasses. It leads to a condition in grazing cattle called "grass tetany" characterized by low blood serum Mg levels due to poor absorption of Mg by the grass under certain environmental conditions. It is best to confirm suspected Mg deficiency with both a soil test and tissue test.

Photo 6. Field view of barley showing sulfur (S) and magnesium (Mg) deficiency (tissue test confirmed S and Mg deficiencies) on a loamy sand soil near Laurel, DE (Photo by R. Taylor).

Can anything be done about the problem or should anything be done? A S, Mg, and potassium (K) containing fertilizer (KMag or Sul-PoMag—potassium magnesium sulfate) can be applied at a very low additional cost. This fertilizer will provide K, Mg, and S to the small grain crop and more importantly to the following soybean crop. Another fertilizer option that contains S and Mg is Epson salts or magnesium sulfate. The choice between the two depends on the costs of each compound and whether soil test K levels are high or not. High levels of soil test K can inhibit the uptake of Mg by grass crops. Even with this addition of S and Mg, the upcoming soybean or other crop should be observed carefully for deficiency symptoms so early intervention can solve developing deficiencies before yield is lost. In the current crop if the crop has headed out, there may be only a minimal potential for yield increase and much of the benefit will accrue from the double-crop portion of the rotation. If applied prior to heading, the crop usually responds enough to cover the cost of both the application and the fertilizer.

Photo 7. Interveinal chlorosis of wheat showing sulfur (S) and magnesium (Mg) deficiency (tissue test confirmed S and Mg deficiencies) on a loamy sand soil near Laurel, DE (Photo by R. Taylor).

The value of tissue testing has been confirmed in past years. When evaluating tissue test results, pay attention not only to the absolute concentration of each nutrient but also the relative ratios of certain nutrients. In the above cases, the relative high N content in relation to the S content confirmed a S deficiency problem. A high K concentration with respect to the Mg concentration would indicate a problem with Mg even if the absolute Mg concentration were not below the critical level.

In the above cited instances of S and Mg deficiency, growers reported exceptional yield responses to the nutrients applied. Deficiency

symptoms did not subsequently appear on a soybean planting that followed the harvest of the small grain.

Photo 8. Field view of wheat showing sulfur (S) and magnesium (Mg) deficiency (tissue test confirmed S and Mg deficiencies) on a loamy sand soil near Laurel, DE (Photo by R. Taylor).
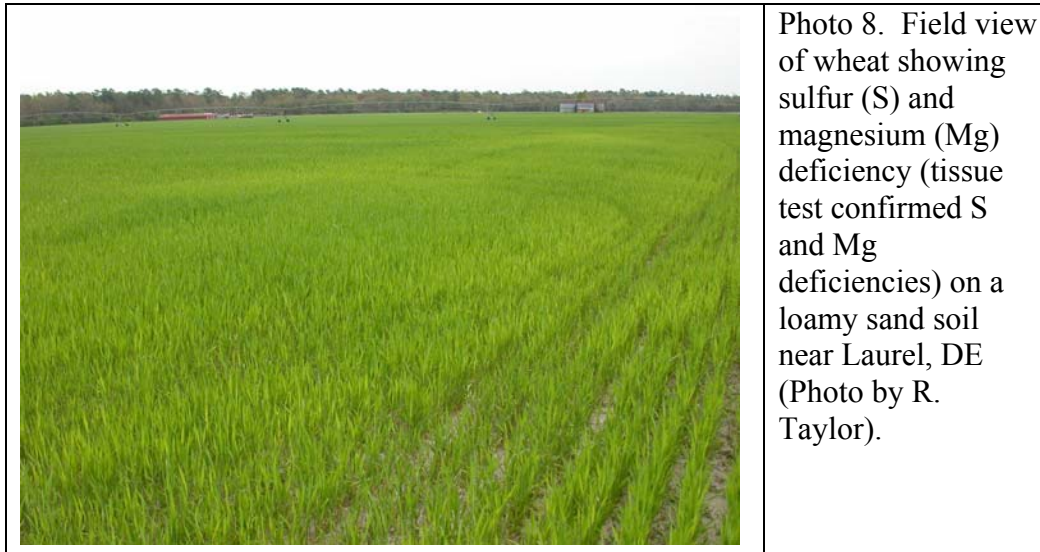
Manganese (Mn)

Although we sometimes find Mn deficiency in small grains in the fall, the most common time that I have observed Mn deficiency is in the spring shortly after a spring green-up N application. Wheat and especially barley are susceptible to Mn deficiency problems especially on soils where soil pH increases with depth. This problem has decreased in the past decade since most of the lime we apply today is very finely ground limestone with low amounts of the coarser limestone fractions. Years ago in situations where the coarser fraction predominated agricultural limestone and lime was applied on a regular (every two or three year) basis, the deeper layers of soil (8-16 inches) were often much higher in pH than the surface soil.

In these instances, the deficiency showed up following spring N application since N and warming soils stimulate crop root growth into deeper soil layers where the high pH soil leads to Mn deficiency. The availability of Mn and other micronutrients not only depends on the amount of nutrient in the soil but also on the soil pH (Photo 9). As soil pH rises, the availability of many micronutrients and especially Mn decreases. The only micronutrient this does not hold true for is molybdenum which increases in availability as the pH approaches neutral.

Photo 9. Interveinal chlorosis of wheat showing manganese (Mn) deficiency on a high pH loamy sand soil (Photo by R. Taylor).

Early scouting of fields is essential in preventing stand loss. The usual interveinal symptoms of Mn deficiency such as seen on soybeans are not as striking in wheat. The deficiency shows up as yellowing of the upper leaves (it's not a mobile nutrient in the plant) or as a faint striping on the leaves. Some plants show grayish spots between the veins that can coalesce into larger spots. Symptoms are sometimes hard to see on young small grain seedlings although poor growth and a gray steel coloration of leaves are often seen. The patterns of yellowing or stunting in the field often are more diagnostic of Mn deficiency than individual plant symptoms (Photo 10).

To confirm the problem, the best choice is to obtain a tissue sample for testing and to pull a soil sample from the affected area and a nearby area showing normal growth. For a tissue sample, take whole plant samples from a number of affected plants across the field but avoid contamination with soil. Again, take a reference sample from an area of normal growth. You should take soil samples in four inch increments and go at least a foot deep to accurately access the impact of soil acidity on micronutrient availability. Be sure to make note on the soil test information sheet of the depth of soil sampled. Foliar Mn application can help the crop recover but more than one application may be needed if the seedlings are very small and the leaf area available for foliar absorption is limited. We typically apply between 1 and 2 lbs of actual Mn per acre. Plant coverage with the spray is very critical for helping the crop recover. Chelated Mn can be used as well as $MnSO_4$ (techmangam). Both fertilizers are effective so the decision is usually made based on product cost. Chelated Mn is often much more expensive than techmangam but do

Photo 10. Pattern of interveinal chlorosis of wheat showing manganese (Mn) deficiency on a high pH loamy sand soil (Photo by R. Taylor).

not try using very low rates (0.25 to 0.5 lb Mn/acre) of chelated Mn to save on cost. Low chelated Mn rates have been shown to be less effective than techmangam. Fast action and complete plant coverage are critical factors to consider.

Copper (Cu)

Copper deficiency was last positively identified on wheat in Delaware back in the 1950's according to conversations I had years ago with Dr. Leo Cotnoir, former soils Professor at the University of Delaware. The deficiency symptom appears as leaf tip die back followed by a twisting or wrapping of the leaves. Copper deficiency can lead to delayed maturity and stunted, misshapen heads. Traditionally, this deficiency is associated with muck or organic soils but Dr. Cotnoir did observe it in northern Delaware on highly limed soils before the widespread use of superphosphate. Superphosphate (0-20-0) contained enough copper to eliminate the symptoms. Today, most producers apply triple super phosphate that does not contain Cu. Copper deficiency is unlikely on soils that have received poultry manure and some biosolids since these products can contain enough Cu to supply crop needs. In soils where the more refined triple-superphosphate has been the sole phosphorus source for many decades or where soil pH is kept near neutral or the soil is relatively high in soil organic matter or has received applications of organic materials low in Cu, this deficiency might occur again. Copper deficiency should be confirmed with a tissue test before applying copper sulfate which is very effective in alleviating symptoms. Copper-containing fungicides also can be effective. A foliar rate of Cu is 0.1 to 0.25 lb actual Cu/acre. Document any applications of Cu since this element can easily build up in the soil to harmful levels and in certain situations Cu application is limited by law.

Wheat Nutrition—Adding an Extra Touch

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With the current wheat price, many producers may be thinking of adding extra nitrogen (N) to push yield potential to the maximum. The high cost of N actually could limit any gain from this approach since we know that in most cases what limits yield is the environmental (water—primarily—and temperature) conditions during grain fill and not N availability. Wheat yield, like corn, responds to additional N in a way that for each additional pound of N applied the incremental increase in yield becomes smaller and smaller until the point of maximum economic yield (MEY). After the MEY point, although more N may increase yields slightly, the extra N actually reduces net profit per acre.

So, what extra touch can be used to increase yield. In a four year study, Bob Uniatowski and the author found that a split application of N could on average add an extra five or more bushels to yield even at the highest N rate applied in the study (160 lb N/acre). Although the actual proportion of N applied at each split wasn't as important as using a split application, the rate of N for the first split (mid-February to green-up in March) should be larger than the second split (growth stage Feekes 5, first node evident above the soil surface) if the plants are not yet at full tiller, were planted late, or did not have enough available N last fall to fully establish. If the first application is at a higher rate, the extra N helps the crop complete the tillering process;

encourages top growth and root formation resulting in a reduced impact from late-season stresses; and, most importantly, helps insure against the possibility that weather conditions will prevent the application of the second split.

The longer the time from N application to stem elongation the greater the risk of N loss from volatilization, leaching, or denitrification. Thus, very early applications of N (mid-January to mid-February) potentially can reduce yield if only a single application is made. Where adequate fall N is available from the soil or applied at planting, late winter/early spring crop N needs will be low so a later first application is preferred. Many growers apply N early in the spring to stimulate tiller production. The majority of yield comes from the primary tillers laid down last fall and an early spring N application or split N application will not alter this. However, the small but significant (especially at today's wheat price) increase we observed can be partially explained by an increase in the number of secondary, smaller heads. Another likely factor is that some of the yield increase from splitting the N into two applications comes from the conservation of fertilizer N (providing late-season N if significant leaching, volatilization, or denitrification occurs). In our study, we observed a split effect even at very high N rates so both factors likely came into play during the study.

No-till Corn Planting into Rye Cover Crop Residues

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Cover crop usage in Pennsylvania and other mid-Atlantic states has increased dramatically over the past few years, and much of the cover crop is cereal rye. Benefits to farmers include soil erosion reduction, nutrient loss prevention, and improved soil quality. Farmers are also increasingly interested in planting no till, and have serious concerns about their ability to successfully plant corn into rye cover crop residues. Rye is typically planted in the fall after corn or soybean harvest, and then grows rapidly in the spring, producing large amounts of biomass once temperatures start to warm up. Many farmers are afraid that they won't be able to get the rye killed in a timely manner, and the resulting large amount of plant material may interfere with planting operations.

For the past few years we have evaluated the effect of rye residues on a corn crop at Penn State's Southeast Research and Extension Center near Landisville, Lancaster County. Rye was planted into soybean stubble in mid-October of 2005 and 2006 at 0, 1.5 or 3.0 bushels/acre, and corn was planted no till at three dates (approximately April 29, May 8, and May 20 in each year)

the following spring. The experimental design was a split plot with 4 replications and corn planting date as main plots and rye seeding rate as subplots. The rye was killed with glyphosate + 2,4-D approximately 10 days before corn planting, and was completely dead at the time of corn planting. Rye was approximately 6 inches, 12 inches, and 36 inches tall at the time of application for the early, mid, and late plantings, respectively. For the third planting only, the rye was rolled with a culti-mulcher (2006, with tines raised) or roller/crimper (2007). The corn was planted in 30-inch rows using a no-till planter set up with residue managers, 13-wave coulters, seed firmers, and one spiked and one solid rubber closing wheel, and calibrated to drop 33,000 seeds/acre. Fertility was 50 lb of N/acre broadcast as 30% UAN within a week prior to each planting, followed by an additional 100 lb N/acre (as 30% UAN) side dressed in row middles at mid season. Starter (7-21-5) was applied with the planter at 2+2. Weed control was with Harness Xtra (2006) or Guardsman Max (2007) applied after each planting. In 2006 armyworms became a problem, and the field was treated with Warrior. No armyworms were observed in 2007. Data included stand counts and yield at the end of the season.

The amount of biomass produced by rye depends on when it is planted in the fall and when it is killed in the spring. In our studies, rye planted in mid October produced about 2000, 4000, and 4200 pounds of above-ground dry biomass per acre if killed around April 20, May 1, and May 10, respectively, regardless of rye seeding rate (2007 data only). Although there were no differences in biomass between the mid and late corn planting time, the rye at the late timing was much taller.

Corn stands were not affected by the rye, with about 31,700 plants per acre, averaged over all of the plots. There was a significant year by planting date interaction for corn yield. In 2006, the planting date by rye seeding rate interaction and the rye seeding rate main effect were not significant, but there were significant differences in corn yield for each planting date, when averaged over rye seeding rate (Table 1). Corn yield decreased as planting date became later. There does appear to be lower yields when corn was planted into rye at the later two planting dates (and higher at the early planting date), but these differences were not statistically significant.

Table 1. Effect of corn planting date and rye cover crop residues on corn yield in 2006.

Corn planting date	Rye planting rate (bu/a)			Mean
	0	1.5	3.0	
	------------------------ bu/a ------------------------			
4/29	170.7	185.5	180.8	179.0[a]
5/4	167.4	149.0	152.7	156.4[b]
5/21	121.7	93.5	95.8	103.7[c]
Mean	153.3[a†]	147.6[a]	143.1[a]	

[†], Means followed by the same letter are not significantly different using LSD (0.05).

In 2007 there was a significant planting date by rye seeding rate interaction. Yields for the first two planting dates did not differ, regardless of rye planting rate (Table 2). Yields for the last planting date were lower than all of the others, and when rye was present yields were even lower.

Rye biomass was only measured in 2007 (Table 2). There was little difference in total dry matter between the middle and late planting, but rye at the late planting was well into the boot stage when it was killed. Corn yields were much lower when rye residues were present at the late planting, compared to the middle planting, and were reduced by nearly 25 to 30 bu/acre compared to plots with no rye. The larger rye plant size (but not biomass) may have interfered with corn growth (allelopathy?, nitrogen immobilization?), resulting in lower yields. Lower plant populations do not explain the differences, showing that the planter was able to place the seed properly.

These data show that with a planter set up properly for no till, corn can be planted into fairly heavy rye residues little or detrimental effect on yield. However, to maximize yield, corn must be planted early, necessitating early killing of the rye cover crop. Rye will probably have more of an effect on corn when it grows taller.

Growers should ensure that their planters are set up to cut through the rye residues, giving proper corn seed placement with good seed to soil contact, and make sure the rye is completely dead when corn planting occurs. Growers should also watch out for insects, as cover crops (and winter weeds) can attract insects like cutworms, and armyworms are also often seen in rye cover crop fields.

Table 2. Effect of corn planting date and rye cover crop residues on corn yield in 2007.

Corn planting date	Rye planting rate (bu/a)			Mean	Dry rye biomass
	0	1.5	3.0		
	------------------------- bu/a -------------------------				lb/a
4/30	188.2[abc†]	188.6[abc]	197.5[ab]	191.5	1985
5/10	201.3[a]	197.4[ab]	185.1[abc]	194.6	4036
5/22	177.8[c]	154.6[d]	148.9[d]	160.5	4226
Mean	189.1	180.2	177.2		

[†], Means followed by the same letter are not significantly different using LSD (0.05).

Effects of Twin-Row Spacing on Corn Silage Growth Development and Yield in the Shenandoah Valley

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Corn grown for grain and silage in the Shenandoah Valley of Virginia has traditionally been planted in 30" wide rows. More recently, many producers have been experimenting with narrow or twin-row spacing configurations. There exists a growing body of literature documenting the potential yield and agronomic benefits from corn spaced in either 15" wide rows, or twin-rows, which are 7.5" wide on 30" centers. The twin-row spacing has particular appeal for many of our dairy operations who often make the decision to harvest forage or grain at or very near to the time of harvest, depending on their storage and use requirements. The appeal of the twin-row spacing is the flexibility to either harvest corn for forage or grain without the investment in specialized harvesting equipment, while at the same time taking advantage of potential yield benefits from the narrow row system. Furthermore, a twin-row system would allow typical in-season crop inputs (side-dress fertilizer, post-emergence herbicide applications) to occur without the danger of crop damage.

A two year study was established in the central Shenandoah Valley to compare the effects of twin-row spacing with conventional row spacing on corn silage yield and growth characteristics using a Great Plains GP1520 precision seeder. In 2006, the field selected was irrigated with a traveling gun system. In 2007, both irrigated and non-irrigated sites were chosen. Plots were arranged in a strip plot design with six replications. The corn hybrids selected for this project were Pioneer Brand 31R87 (irrigated sites in 2006 and 2007) and Pioneer

Figure 1. Observed plant height differences between row spacing treatments.

Brand 31G71 (non-irrigated site in 2007). Respective relative maturity ratings on these hybrids are 120 and 118 days. Hybrids were planted no-till into killed barley cover crop in early May at seeding rates to achieve 31,000 plants per acre.

Plant population was determined in all plots after corn emergence. In 2006 and 2007 stand counts were taken at 21 and 52 DAP (V2 and V8 development stage) and 61 DAP (V9 stage)

respectively. Plant height was measured at the V8 growth stage in 2006 and the V9 growth stage in 2007. Visual ratings of disease and insect damage were taken from the plants at various times throughout the growing season. The corn silage was harvested in mid-September with a New Holland (New Holland, PA) pull-type three-row harvester equipped with a kernel processor. The center six rows from each plot were harvested, leaving six rows on either side of each row spacing treatment for a buffer. During harvest, grab-samples were collected and compiled for forage analysis to estimate dry matter content, digestibility and nutrient content. Harvest samples were immediately frozen and sent to Cumberland Valley Analytical Services for wet chemistry analysis.

Row spacing did not affect plant densities and final plant densities were within 90% of target densities (Table 1).

Table 1. Plant density at the second and eighth leaf stages (2006) and ninth leaf stage (2007) under conventional- (30") and twin- (7.5" on 30" centers) row spacings; and plant height measured at the eighth leaf stage in 2006.

	Plant Population				Plant Height
	2006		2007		2006
Row spacing	V2 Irr[†]	V8 Irr	V9 Irr	V9 Non	V8 Irr
	----------------------------plants ac^{-1}------------------------ ---				inches
Twin	28000	28000	28670	29250	21.6
Conventional	28000	27000	27580	27630	19.8
Average	28000	27500	28125	28440	20.7
LSD (0.05)	NS	NS	NS	NS	NS

† Growth stage and irrigation treatments where Irr = irrigated and Non = non-irrigated

Final plant populations were nearly optimum for corn silage yield and quality under growing conditions in our region. No difference was observed in plant densities measured at the V2 and V8 growth stage in 2006, indicating that plant survival during the growing season was excellent. Row spacing did not affect plant height measured at the V8 growth stage in either year (Table 1). While not significant, height differences were observed as the corn matured and individual row spacing treatments could be picked out (Figure 1).

Visual ratings of insect and disease pressure between row spacing treatments were not different. Minor fungal disease (gray leaf spot, northern corn leaf blight, rust) was observed in the irrigated corn treatments in both 2006 and 2007. No significant insect damage was observed at any site/year combination. Row spacing did appear to affect weed

Figure 2. Typical effect of row spacing on weed control.

infestation, although this was not quantified. Anecdotal evidence indicated that weed pressure was greater in the conventional row spacing treatments (Figure 2). The herbicide regiment for

this study was quite robust, with both PRE applications of contact and residual herbicides (Lumax + Aatrex + Princep + Gramoxone) and concurrent POST applications (Prowl H2O + Roundup Original Max). Although weed control was very acceptable between treatments, there were visible and striking differences in weed density observable at harvest. Canopy closure was more rapid and sustained within the twin-row treatments, and thus less light interception was available to germinate weed seed. This is an interesting phenomenon that should be explored further.

Table 2. Dry matter (DM) content, DM yield, crude protein (CP), total digestible nutrients (TDN), net energy for lactation (NE_L), acid detergent fiber (ADF) and neutral detergent fiber (NDF) for two row spacings averaged across the 2006 and 2007 growing seasons.

Row spacing	DM content	DM Yield	CP	TDN	NE_L	ADF	NDF
			----------------------------------%--------------------------				
	%	ton ac^{-1}	--------------				
Twin	38.7^{a*}	22.4^a	7.3^a	71.4^a	0.8^a	23.7^a	42.2^a
Conventional	40.5^a	19.9^b	7.6^a	70.5^a	0.7^a	25.0^a	44.0^a

*, Means followed by a common letter are not significantly different at the 0.07 level of probability.

Twin-row corn yielded 12.5% greater than conventional-row corn (Table 2). This significant yield advantage was consistent across years and sites in this study. The growing season in 2007 was exceptionally dry in the Shenandoah Valley and corn yield differences between twin-row and conventional row spacing were amplified. In the non-irrigated trial in 2007, visual observations of water use efficiency between row spacing treatments were quite revealing, but were not quantified. For example on 18 June, corn in the conventional row spacing treatments were exhibiting rolled leaves and were under obvious drought stress; however, corn in the adjacent twin-row strips had not yet rolled (Figure 3). Future research will attempt to quantify this phenomenon. Cornell researchers led by Dr. Bill Cox in a 2006 report stated that they performed their research under non-irrigated conditions and they

Figure 3. Example of improved water use efficiency in twin-row corn versus conventional row spacing. Note rolled leaves.

also observed significant hybrid differences in response to row spacing. In this study (Virginia), there were no differences observed between the two corn hybrids selected.

Forage quality is also a very important consideration for dairy producers when selecting corn hybrids or implementing production practice changes. In this study, row spacing had no affect on CP, TDN, NE_L, ADF or NDF measured from sub-samples collected at harvest (Table 2). Interestingly, the irrigated site in 2007 did have a greater CP level than either of the other site/year combinations, but row spacing did not influence this response (data not shown).

Twin-row spacing as an alternative planting practice for corn silage production in the Shenandoah Valley leads to greater corn silage yields through greater water use efficiency and faster canopy development. Forage quality and DM content at harvest were not impacted by row spacing. In this study, the Great Plains GP1520 precision drill was able to consistently and precisely achieve uniform plant spacing within rows, which led to fewer skips and a very desirable "picket-fence stand" (Figure 4).

Future work will attempt to determine precision of planting as a potential factor. Both planters in this study were able to achieve 90% of the targeted plant densities. In this study, plant density was not a factor. Future work will examine the possibilities of increasing plant population in a narrow-row system. Partial budget analysis of conventional, 15" and twin-row spacing by researchers at Cornell University led by Dr. Bill Cox determined that the added expense of the precision drill could be justified with as little as 600 acres of corn silage. While only a handful of dairies in the Valley grow this much corn silage, the cost of the planter could easily be justified by the many custom operators who plant corn in the region.

Figure 4. Precise plant placement achieved from the Great Plains GP1520 precision drill.

Performance of Early Maturing Soybean Varieties in Pennsylvania

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Over the past two decades, growers in some parts of the country have switched to growing earlier-season soybeans in order to avoid the effects of late-season drought on seed set and final yield. Earlier-maturing soybeans will flower earlier in the season, and may be able to out-yield full-season soybeans in low-rainfall years. Other advantages of shorter season soybeans include spreading harvest labor, avoiding weather problems during harvest time in late fall, and allowing for earlier small grain or cover crop planting.

Field experiments, supported by funding from the Pennsylvania Soybean Promotion Board, were run at Penn State research farms in Lancaster and Centre Counties in 2005 and 2006 to evaluate the grain yield and quality of early maturing soybean varieties compared to soybeans of maturity normally grown in the area. The varieties were obtained from several companies and ranged from maturity group (MG) 2.2 to 4.3 in Lancaster County, where mid MG 3 to early MG 4 soybeans are normally grown, and MG 1.7 to 3.6 in Centre County, where early to mid MG 3 soybeans are normally grown. The varieties were planted by May 5 in both Lancaster and Centre Counties in a randomized complete block design with four replications. Large alleyways were left between the plots to allow harvest of the varieties as they became ready, and harvest ranged from mid September to early October. Grain quality (percent crude protein and oil content) was evaluated at the Penn State Crop Quality Laboratory.

In Lancaster County, soybean yields ranged from 46 to 95 bu/a, and regression analysis showed yields were not significantly affected by maturity (P=0.397). However, there was a trend towards better yields for varieties in the MG 2.7 to 3.7 range (Figure 1). While yields for each extreme were lower, the earlier (MG 2.2-2.5) performed as well as or better than the full-season (MG 4.0 or greater) varieties. In Centre County, yields ranged from 32 to 61 bu/a, and later maturity soybeans tended to yield better than earlier varieties, although the correlation was not strong.

Rainfall occurring in the month of August may explain the differences in response at the two sites. More rain fell during August in both years at the Centre County site than in Lancaster

County (Table 1). August was dry in Lancaster County in both years. It is possible that dry weather when the MG 4 soybeans would typically be filling pods did not allow them to reach their full yield potential (1.18 inches in August 2005, with most on August 27 and 28; 1.58 inches in August 2006 in several widely scattered minor events). The earlier-maturing soybeans may have been able to set more seed and fill pods prior to the droughty conditions. In Centre County, 2.78 inches of rainfall occurred in August 2006, with more rain in the first part of the month than in Lancaster County. This possibly allowed the later-season varieties to perform better. There was no effect on grain crude protein or oil content, or on grain disease incidence (data not shown).

These data show that soybeans of maturity groups 0.5 to 1.0 units less than those normally grown in the area can yield as well as "normal" maturity group soybeans, at least when there are drought conditions in August. It is important that early maturity soybeans be planted early, as observations on our production acres have been that early maturity soybeans that are planted late (after May 15) will produce shorter plants, possibly with fewer nodes and pods, than later maturity soybeans planted at the same time. General recommendations for growers considering earlier soybeans would be to try them on a portion of their acres and prioritize planting them early in the season.

Figure 1. Soybean yield trends for various maturity groups in Centre and Lancaster Counties, PA, combined over 2005 and 2006. Regression equations:

Centre: Yield = $31.7 + 6.13$(MG), P = 0.007, $R^2 = 0.30$
Lancaster: Yield = $82.5 - 4.2$(MG), P = 0.397, $R^2 = 0.03$
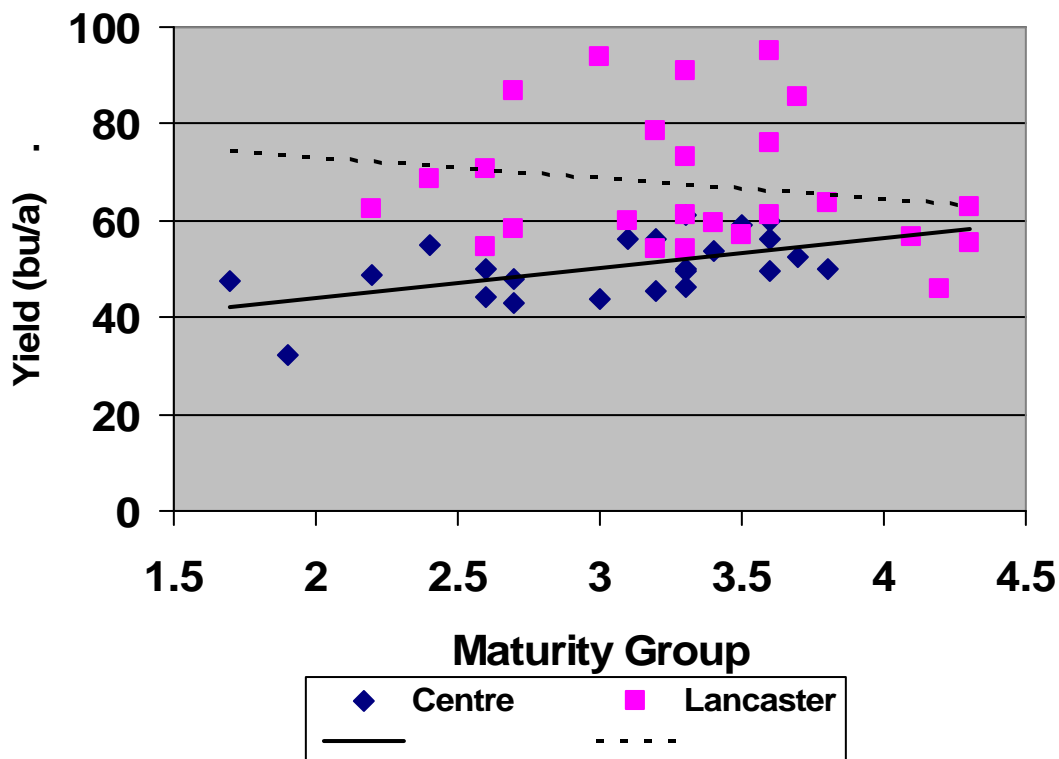
Table 1. Total rainfall during the month of August in 2005 and 2006 at the Centre and Lancaster County research sites.

| Site | Total rainfall in August: | |
	2005	2006
	-------- inches --------	
Centre	3.48	2.78
Lancaster	1.58	1.18

Corn Ear Formation: Effects of Early Season Dry Weather

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Many dryland corn fields across Ohio and the Mid-Atlantic probably will experience exceptionally dry conditions sometime during the upcoming growing season. Moisture stress during the early vegetative stages of corn development is atypical in Ohio but for some areas of the East the long-range forecast suggests very dry spring. Last year in Ohio, some areas of the state received less than a 1/2 inch of rain between mid-April and late spring/early summer when most corn ranged from about V5 (the five leaf collar stage) to V7 or slightly beyond. Ear formation is probably well underway in fields at the more advanced stages of development (V7-V9). However as early as the V4 to V5 stage, ear shoot initiation is completed and the tassel initial can be observed with a hand lens on the top of the growing point. During the rapid phase of corn vegetative growth (which generally starts by V7), ear yield components are being determined. Kernel row numbers per ear are generally established by about V12.

Will early season moisture stress as seen in 2007 impact ear formation and yield potential? It takes fairly severe stress conditions during the early vegetative growth stages to impact kernel row numbers per ear. Kernel row numbers are usually less affected by environmental conditions than by genetic background. Therefore, in most cornfields, it's unlikely that kernel row numbers will be impacted significantly by early season dry conditions. However unlike kernel rows per ear, kernels per row can be strongly influenced by environmental conditions. Determination of kernels per row (ear length) is usually complete about one week before silking (R1) or about the V17 stage. Severe drought stress during the two weeks prior to pollination can reduce kernels per row and lead to a significant reduction in grain yield.

The lack in uniformity in crop emergence and development resulting from dry soil conditions (and soil crusting in some areas) is more likely to affect yield potential adversely than ear formation. It's not unusual to see fields that were planted in late April and early May with corn ranging in growth stage from V2 to V7 and plant height from 5 to 20 inches. When plants in the

same field/row are more than two leaf stages apart in growth staging, the younger plants tend to contribute little to the field's ultimate yield potential and instead act as weeds competing for the limited water, sunlight, and nutrients available.

Survey of Nematode Populations and Prevalence in Virginia Corn Fields, 2007

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Reports of nematode damage in eastern Virginia corn fields, especially in the Middle Peninsula, have increased in recent years. Diagnosing the symptoms of nematode damage to corn can be difficult because they appear similar to many other causes. Root injury caused by nematodes can result in symptoms that are similar to nutrient deficiencies, soil compaction, root rots, herbicide carryover, and other problems. In fact, nematode feeding is often only blamed when most of these other problems are ruled out. Of course, the only way to diagnose nematode damage in corn is by soil samples analyzed by a qualified nematode testing lab. Shifts in nematode populations can be expected with changes in farming practices including: conversion to continuous no-till; the movement away from wheat in the crop rotations; changes in corn genetics; and the conversion from in-furrow insecticide/nematicide treatments to seed-applied treatments.

In a 2007 study funded by the Virginia Corn Board, a group of agents and specialists initiated a study to assess the incidence and severity of nematode damage in corn fields. Soil samples were taken from **suspected problem areas** during the growing season and sent to the Virginia Tech Nematode Diagnostic and Assay Laboratory for characterization. The kinds and numbers of nematodes were recorded for each sample and populations above economic threshold levels for crop damage and possible crop damage were diagnosed. Thresholds for damage were based

on previous field surveys and on-farm tests in the 1980's and 90's as listed at http://ipm-www.ento.vt.edu/nipmn/VA-IPM/updates/nematode/frames.html. It is our intention that fields or areas within fields that were considered problematic will be revisited for site selection of on-farm research and/or demonstration trials in 2008.

In 2007, 67 samples from fields with some type of production problem from 14 Virginia counties were submitted. Based on current nematode thresholds and recommendations, 23 of the samples indicated a nematode problem and 25 revealed a possible problem. Samples noted as having a "possible problem" will likely exhibit economic losses only if the growing season in unfavorable, ie. drought; however if the season is favorable, the corn will not suffer a significant loss. Stubby-root and lance nematodes were the most common species found. Lesion nematodes were fairly common, while root-knot and dagger were less common. Damaging levels of sting nematode, a species that can cause significant yield loss in sandy soils even at very low population levels, were found in 5 samples from Southampton County. According to current nematode thresholds, this survey indicated that nematodes were causing yield loss in some corn fields. We need to expand our efforts to get a better understanding of how much yield loss is occurring in fields with a known population of nematodes.

The results of the survey are summarized in table 1. The key for the recommend column is as follows: A—Nematode problem not detected; B—Possible nematode problem if crop is stressed by other factors; C—Nematodes are a problem; control options are advisable. Numbers are reported as the number of nematodes per 500 cc's of soil (approximately one pint.). The results are color coded: red means that a particular nematode was responsible for the C recommendation; orange shows that a particular nematode may cause damage if the growing season is unfavorable and results in a B recommendation, and green indicates that a particular nematode was present, but not in high enough numbers to be of concern which gives an A recommendation.

Table 1. Nematode kind, number, and recommendation by county in Virginia, 2007.

County	Lesion	Root-knot	Cysts	Stubby root	Dagger	Stunt	Sprial	Lance	Ring	Sting	Pin	Recommend
Chesapeake	0	0	220	150	0	100	790	240	0	0	0	C
Chesapeake	210	0	140	60	30	110	690	160	0	0	0	C
Chesapeake	210	0	10	60	30	50	360	140	0	0	0	C
Dinwiddie	30	0	10	440	330	0	0	0	0	0	0	C
Essex	50	0	0	40	40	20	0	430	0	0	0	C
Essex	40	90	0	40	30	90	150	410	0	0	0	C
Essex	280	0	0	0	10	40	390	400	0	0	0	C
Greensville	0	0	0	520	0	990	30	120	0	0	0	C
Northumberland	10	0	0	300	20	290	0	110	0	0	0	C
Prince George	40	1720	0	360	30	290	610	130	10	0	0	C
Prince George	560	0	0	0	0	40	400	30	0	0	0	C
Southampton	0	0	0	20	0	0	0	0	0	480	0	C
Southampton	0	10	0	30	0	20	10	0	0	190	0	C
Southampton	0	0	0	360	0	0	0	310	0	80	0	C
Southampton	0	0	0	20	0	160	10	30	0	40	0	C
Southampton	0	0	0	10	0	100	0	60	0	20	0	C
Southampton	0	0	0	110	10	0	0	0	0	10	0	C
Southampton	0	10	0	840	20	380	0	0	60	0	0	C
Southampton	0	10	0	960	0	440	10	0	10	0	0	C
Surry	0	0	0	0	0	410	0	1360	0	0	0	C
Surry	70	530	0	180	0	170	130	150	0	0	0	C
Chesapeake	180	0	80	40	70	150	1170	100	0	0	0	B
Dinwiddie	20	0	40	110	0	0	130	10	0	0	0	B
Essex	70	10	0	10	10	0	600	200	0	0	0	B
Essex	0	0	0	0	0	250	160	150	0	0	0	B
Essex	100	0	0	0	0	180	160	100	0	0	0	B
Essex	320	0	50	0	0	0	180	80	0	0	0	B
Greensville	20	0	0	40	0	50	0	40	20	0	0	B
Greensville	0	130	0	180	0	30	3030	50	0	0	0	B
King & Queen	0	140	0	0	0	70	40	110	0	0	0	B
Northumberland	330	0	0	0	10	0	300	240	0	0	0	B
Prince George	0	210	0	20	10	80	10	20	0	0	0	B
Surry	0	0	0	110	0	320	0	0	0	0	0	B
Surry	10	60	0	80	10	0	0	0	0	0	0	B
Amelia	0	0	0	10	0	610	0	10	0	0	0	A
Dinwiddie	0	0	0	10	0	200	0	0	0	0	0	A
Essex	0	0	0	0	0	110	130	70	0	0	0	A
Essex	50	0	0	0	0	90	180	40	0	0	0	A
Essex	40	0	30	0	0	20	130	10	0	0	0	A
Greensville	0	0	0	0	0	0	0	10	70	0	0	A
Greensville	0	0	0	0	0	30	0	40	0	0	0	A
Mathews	130	90	0	10	0	20	190	0	0	0	10	A
Prince George	0	0	0	0	10	0	0	0	0	0	0	A
Prince George	0	0	0	0	0	140	440	0	0	0	0	A
Surry	10	0	0	0	0	30	20	0	10	0	0	A

Improving the Efficiency of Surface Applied Poultry Manure in No-till Corn Production

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Many farmers in Maryland and other areas with a long-term history of applying poultry manure and soils now high in available phosphorus (P) continue to want to plant no-till corn following a surface application of animal manure, including poultry manure. However, research has shown that planting no-till corn following a surface application of poultry manure leads to poor recovery of the surface applied nitrogen (N) in the manure. Poor N recovery from the manure may be caused by N volatilization, usually as ammonia, N leaching via rainfall, and the loss of N by denitrification following periods of heavy rainfall.

A study was conducted from 2005 through 2007 to evaluate several tillage methods to partially incorporate the poultry manure and an additive that possibly would reduce N losses from ammonia volatilization or nitrate leaching/denitrification. The additive used was Agrotain's Super N in 2005 and Agrotain Plus in 2006 and 2007. Tillage methods included no-till, shallow incorporation methods, and a complete tillage system of chisel plowing followed by discing two times. Corn was planted after the manure application and any tillage. Tillage methods occurred within 24 hours of the manure application. Poultry manure was applied at a 2 ton per acre rate that will provide approximately the removal rate of P but not enough N to meet crop needs.

The tillage and urease/nitrification inhibitor treatments are listed in Table 1 as well as the observed yields for each year of the study. In manure treatments where additional N was not supplied as a sidedress application, the average difference between a tillage/Agrotain treatment with and without 80 lbs N/a applied as 30 percent urea-ammonium nitrate solution (UAN) at growth stage V8 (eight leaf collars visible) was 33.9 bu/a and ranged from 26.8 (treatment 1) to 39.7 (treatment 7) bu/a. The control check where no manure was applied averaged 55.6 bu/a without sidedressed N and 122.8 bu/a with 80 lb/a sidedressed N or a difference of 67.2 bu/a, nearly twice the average of the ten treatments.

Surface applied poultry manure with no type of incorporation gave the poorest corn yields (no-till corn—treatment 1). Of the poultry manure applications not receiving Agrotain Plus, highest yields came from using the Zone Till implement (treatment 8) or the V-Ripper (treatment 7) after the broiler manure was applied (Table 1). Over the three year period the Zone Till implement gave the highest corn yields. The V-Ripper produced the second highest corn yields

over the three year period. The difference might occur since the ripper shank makes a narrow slot in the soil for root penetration and aerates the soil while the slanted coulters of the Zone Till implement works and covers the poultry manure and then the rolling basket produces a good seedbed for planting corn. The V-Ripper produced very good yields possibly because it seemed that most of any rainfall run-off flowed into the slot made by the ripper shanks and were recovered by the corn root system. It may also be possible that water induced movement of poultry manure into the slot was used by the crop. The ripper shanks loosened the soil for easy root penetration.

Table 1. Corn yield with 2 tons/acre of poultry manure broadcast preplant and followed with 80 lbs nitrogen per acre at sidedress time from 2005 to 2007 on a Mattapex silt loam soil in a continuous no-till corn rotation at the University of Maryland Poplar Hill Research and Education Farm.

Treatments	Year			
	2005[††]	2006	2007	Average
1. Broadcast manure followed by no-till corn	155.9[ef]	133.5	114.4	134.6
2. Broadcast manure treated w/Agrotain Plus (Agrotain, a urease inhibitor,+ DCD, a nitrification inhibitor)—no-till corn	166.3[d]	139.4	124.4	143.4
3. (2006/07) Broadcast manure, incorporate 1X[†] with Great Plains no-till drill; (2005) Broadcast manure, incorporate with tractor mounted rotary hoe 1X	156.8[e]	151.4	125.7	144.6
4. (2006 & 2007) Same as treatment 3 but manure was treated with Agrotain Plus; (2005) Same as treatment 3 but manure was treated with Agrotain Super N	181.1[ab]	153.4	134.3	156.3
5. (2005 & 2006) Broadcast manure, incorporate w/Great Plains Turbo Till implement; (2007 broadcast manure, incorporate 2X with Great Plains no-till drill)	169.3[cd]	158.1	127.4	151.6
6. Same as treatment 5 but manure was treated with Agrotain Super N	175.8[ab]	159.2	129.9	155.0
7. Broadcast manure and used V-Ripper (depth 10”) between corn rows after manure application	178.4[ab]	160.5	130.1	158.3
8. Broadcast manure and used a Zone Till within-row ripper (11”) after manure application	185.0[a]	156.6	138.9	160.2
9. Broadcast manure, incorporated manure using chisel plow, field cultivator and disking soil twice after manure application	183.4[ab]	159.8	127.9	157.0
10. Broadcast manure, incorporated manure by disking soil twice after manure application	184.5[a]	156.3	129.9	156.9
11. Check, no manure, with sidedress (80 lb N/A) nitrogen	149.3[f]	137.8	81.4	122.8

[†], 1X means the operation was done one time. [††], In 2005, the calculated LSD (least significant difference among means was 7.07 bu/A; means followed by the same letter were not significantly different.

Agrotain Plus improved the efficiency (produced more grain per pound of applied N) of poultry manure N in the following treatments: no-till, tillage one time with the Great Plains no-till drill, and with the Turbo Till implement (Table 1). Poultry manure treated with Agrotain Plus then incorporated either one time with a Great Plains no-till drill or the Great Plains Turbo Till implement gave yields similar to the more aggressive tillage systems of disking the soil twice or the chisel plow/disk combination following application of poultry manure. The shallower tillage implements when combined with an application of Agrotain Plus on poultry manure can be as efficient as the more aggressive tillage implements when no Agrotain Plus is used.

Agrotain Plus generally improved the N use efficiency of the manure regardless of whether additional N as sidedressed 30 percent UAN was applied (Table 2). When averaged over the three growing seasons, manure with Agrotain Plus produced 7.1 bu/acre more than manure without Agrotain Plus. This difference was similar (9.5 bu/acre) when no sidedress N was applied.

Table 2. Comparison of corn yield following broadcast poultry manure applications with and without Agrotain Super N (2005) or Agrotain Plus (2006 and 2007) when fertilized or not fertilized with sidedressed N at the University of Maryland Poplar Hill Research & Education Farm, 2005-2007.

Comparisons	2005[††]	2006	2007	Average
With sidedress N[†]	bushels/acre			
Average of treatments with Agrotain Plus	174.4 [a]	150.7	129.5	151.5
Average of treatments without Agrotain Plus	160.7 [b]	147.7	122.5	143.6
			Difference	7.1
Without sidedress N				
Average of treatments with Agrotain Plus	123.2 [c]	132.0	110.2	121.8
Average of treatments without Agrotain Plus	115.7 [c]	117.9	103.2	112.3
			Difference	9.5

[†], Nitrogen was sidedressed as 30% UAN at the 8th leaf stage of growth. [††], Means followed by the same letter were not significantly different.

An important question for the study was whether the limit of 2 tons per acre of poultry manure was adequate to not increase soil test P levels. At a sampling depth of 0 to 8 inches and averaged across treatments 1 to 10, soil test P levels were only slightly higher than those for the control no manure treatment and slightly lower than the initial 2005 value (Table 3). However when compared with the change in the control treatment from 2005 to 2007 (a drop of 41 FIV's), there was only a 7 FIV drop from 2005 to 2007 for the average of treatments 1 to 10. At the shallow sampling depth that is indicative of the possible loss of soluble P through surface runoff during rainfall events, the increase for treatments 1 to 10 versus the control treatment in 2007 was 29 FIV's. Treatment 7 which incorporated the use of the V-Ripper to a depth of 10 inches between corn rows after manure application showed a substantial reduction in soil test P FIV values between 2007 and 2005 at both the shallow (0-2 inch) and deeper (0-8 inch) sampling depths. It can be speculated that the V-Ripper was moving acid subsoil into the upper soil profile levels and the iron and aluminum from the subsoil were fixing P and lowering the plant available P levels.

Table 3. Soil test phosphorus values (FIV units) for various tillage and Agrotain treatments with an application of 80 lbs/a of sidedress N prior to and following a three year study at the University of Maryland Poplar Hill Research & Education Farm, 2005-2007.

| Treatments | Soil Sampling Depth | | | |
| | 0 – 2" | | 0 – 8" | |
	2007	2005	2007	2005
1. Broadcast manure followed by no-till corn	131	98	103	101
2. Broadcast manure treated w/Agrotain Plus (Agrotain, a urease inhibitor,+ DCD, a nitrification inhibitor)—no-till corn	172	115	130	125
3. (2006/07) Broadcast manure, incorporate 1X[†] with Great Plains no-till drill; (2005) Broadcast manure, incorporate with tractor mounted rotary hoe 1X	154	104	131	110
4. (2006 & 2007) Same as treatment 3 but manure was treated with Agrotain Plus; (2005) Same as treatment 3 but manure was treated with Agrotain Super N	142	102	110	113
5. (2005 & 2006) Broadcast manure, incorporate w/Great Plains Turbo Till implement; (2007 broadcast manure, incorporate 2X with Great Plains no-till drill)	140	114	104	118
6. Same as treatment 5 but manure was treated with Agrotain Super N	123	107	99	122
7. Broadcast manure and used V-Ripper (depth 10") between corn rows after manure application	86	126	77	121
8. Broadcast manure and used a Zone Till within-row ripper (11") after manure application	101	115	112	118
9. Broadcast manure, incorporated manure using chisel plow, field cultivator and disking soil twice after manure application	134	110	124	126
10. Broadcast manure, incorporated manure by disking soil twice after manure application	146	115	121	121
Mean treatments 1 to 10	133	111	111	118
Check, no manure	104	113	98	139

Pastures Need Time to Adapt to Drought Stress

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We often think of drought stress as if it were a switch in the plant. One moment the plant is well watered and the next it drought stressed, just like flipping the light on and off. In contrast, the plant actually adapts as soil moisture becomes limiting. It is important that we give our pastures time to adapt to drought. This will allow plants to acclimate to lower moisture and speed recovery after the rain finally comes.

The first visible effect of drought stress on plants is reduced shoot growth. Plant leaves grow by increasing cell numbers through division and then expanding these cells using water in much the same way as air is used to blow up a balloon. When water is limiting cell expansion is reduced. It is important to note that cell expansion slows before cell division. This means that the plant actually accumulates a stockpile of cells in the leaves that have not expanded due to limited moisture. If these leaves can be maintained, they will exhibit very rapid growth after moisture is restored.

As shoot growth slows, photosynthesis continues, which results in an increase in sugars and carbohydrates in the plant since these energy sources are not being utilized for leaf growth. This increase in sugars and carbohydrates (energy) helps the plant to adjust to the drought stress, maintain the growing point during dormancy, and regrow after dormancy. So it is important to leave at least 2-4 inches of leaf area on pastures at all times. Grazing closer reduces the plants ability to adapt to drought stress.

As the drought worsens holes in the leaves call stomata close to reduce water loss from the plant. This not only reduces water loss, but also limits carbon dioxide from entering the leaf. Since carbon dioxide is required for photosynthesis, this process can no longer continue after the stomata have closed. In addition, water evaporating from the stomata also cools the plant leaf. After the stomata close, leaf temperatures increase and the leaf will eventually overheat and die. The loss of leaf tissue is a survival mechanism of the plant which allows all excess water to be shifted to maintain the growing point of the plant. Although the plant appears dead, it is really in a state of dormancy and will initiate growth when conditions are favorable. During dormancy the plant still consumes a small amount of energy to maintain the growing point and as plant breaks dormancy energy will be required for growth since leaf tissue has died.

Not all plant species respond to drought and grazing in a similar manner. Below is a brief description of the responses of common forages species to drought and grazing.
Alfalfa. Alfalfa possesses a deep taproot making it one of our most drought tolerant legumes. During periods of severe drought and high temperatures, alfalfa will go dormant but is generally not damaged. During these periods alfalfa will bloom at a short height, and can be grazed off without injuring the stand.

Red Clover. Red clover also possesses a taproot, but it is much shallower than alfalfa. Drought stress can injure established stands of red clover, shorting stand life. Hot and dry conditions are especially damaging to newly established seedlings.

White Clover. White clover is a relatively shallow rooted legume. Production during drought is low, but plants usually persist and regrow from either stolons or hard seed.

Sericea lespedeza. Sericea is a deep-rooted warm-season legume that has good drought tolerance. It thrives on acid soils with low fertility where other legumes will not persist.

Orchardgrass. Orchardgrass is a strong perennial grass with fair drought tolerance. This grass will persist during hot and dry conditions if it is not overgrazed. Orchardgrass will not tolerate

close and frequent grazing and therefore works best in rotationally grazed systems. Orchardgrass is not as well adapted to southern and eastern Virginia and will not persist under poor management.

Tall Fescue. In Virginia, endophyte infected tall fescue is the best adapted cool-season grass and will in most cases survive even severe drought. It is more tolerant of mismanagement that orchardgrass, but also responds well to rotational grazing. The endophyte imparts grazing and drought tolerance to tall fescue, thus endophyte free varieties are not as tolerant to drought stress, but can survive with optimal management.

Kentucky Bluegrass. Bluegrass is a sod forming perennial cool-season grass that tolerates close and frequent grazing and is best adapted to the higher elevations and areas west of the Blue Ridge Mountains. This grass possesses a relatively shallow root system and is not drought tolerant. Bluegrass routinely goes dormant during the summer months when temperatures are high and moisture is limiting. However, bluegrass normally resumes growth in the fall when soil moisture is abundant and temperatures are lower.

Bermudagrass. Bermudagrass is a sod forming perennial warm-season grass that is best adapted to the Southern Piedmont and Coastal Plains Regions of Virginia. This grass tolerates close and frequent grazing and possesses excellent drought tolerance. As previously noted, even bermudagrass requires some water to remain productive. An advantage of bermudagrass is that it produces about twice as much dry matter per unit of water used. It also responds well to smaller amounts of water supplied by summer thunderstorms compared with cool-season grasses.

Crabgrass. Crabgrass, commonly considered a weed, can provide high quality summer grazing. Research at Virginia Tech has shown that crabgrass consistently produces 6000-8000 lb DM/A. Compared with bermudagrass, crabgrass responds differently to drought. Crabgrass growth slows down significantly when moisture is limiting, but resumes rapidly after even small amounts of rainfall.

Native Warm-Season Grasses.   These grasses are indigenous to the United States and include switchgrass, eastern gamagrass, indiangrass, and big and little bluestem. They must be rotationally grazed and will not persist under close and frequent defoliation. These grasses have excellent drought tolerance and fair tolerance to poor drainage. One factor that limits more widespread use of native grasses is that they can be difficult to establish. Seed dormancy is a major factor affecting establishment and must be broken prior to planting. In most this can be accomplished by wet-chilling the seed for a period of 4-6 weeks just prior to planting.

The single best thing that you can do for your pastures as they go into a drought period is to give them time to adapt by limiting grazing. This can be accomplished by placing animals in a sacrifice paddock and feeding hay.   Although it will take discipline on your part to resist the temptation of opening all the gates, in the end it will limit damage to one paddock and speed the recovery of all other paddocks.

Why Shouldn't I let the Animals Graze that Close

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Early in the spring before cool-season forages really take off, it is often tempting to place animals on pastures and let them graze as close as they want and in doing so you can reduce your need for hay/grain and allow the animals out of confinement. This practice is especially prevalent among those who are not set up for rotational grazing or don't have the time to spend moving animals from pasture to pasture. The potential for damage to your pasture with this practice depends on your stocking density (animal units per acre), pasture species, animal species, weather, fertility, and a number of other factors. I often see this practice used by the small grazer who has limited land with which to work (Photo 1). Let's discuss a few of these factors with emphasis of their impact on pasture health.

Photo 1. An overstocked (2 horses per acre), continuously grazed pasture showing the impact of early grazing on stand density (Photo courtesy R. Taylor). In the upper left corner, note the winter hay fed site.

Stocking density or the number of grazing animal units per acre often is determined by outside circumstances such as acres of pasture available and number of animals on the farm instead of by forage availability and forage (pasture) growth rate. Early in the spring as grasses and legumes are coming out of the winter and using up the last of their stored energy (starch-sugar-carbohydrate) reserves to produce new leaves, the amount of leaf area available to

intercept sunlight and fix carbon dioxide as sugars is very limited. Pasture plants left ungrazed quickly produce enough leaf area to become self-sustaining and capable of sustaining the rapid growth rate we traditionally think of for cool-season forages in late spring. If animals are allowed to graze this new growth before the pasture plants reach the self-sustaining point, the plants are forced to use any remaining stored food reserves to generate new leaves. When the food reserves eventually are completely used up, the plant, where possible, will cannibalize existing tissue (roots and other tissues) to support new growth. If close grazing persists, plants run out of energy or tissues to sacrifice and die or are weakened to the point that even if grazing is halted the plants are not able to compete with germinating weeds or other plants not favored by the grazing animal.

Pasture species is another key factor in how well the pasture can adapt to early close grazing. Pasture species that have many basal (low growing) leaves are generally less susceptible to close grazing. Kentucky bluegrass, the ryegrasses, the festuloliums, and to some degree tall fescue have basal leaves that allow them to tolerate some close grazing. Kentucky bluegrass and the ryegrasses will tolerate early close grazing the best.

Horses are one of the closest grazing animals and can often keep pastures grazed right down to the soil level (Photo 2). Horses also graze almost continuously due to the small size of their stomach and the fact that fiber digestion takes place in the enlarged cecum that comes after the small intestines. In addition, we often overstock horses on pastures and this places additional stress on pastures. Whenever you graze early in the season, be sure to understand the grazing habits of your animals and avoid adding additional stress to pastures as they begin spring growth.

Photo 2. A pasture (April 5) grazed to within a ¼ to ½ inch of the soil surface by horses (Photo courtesy R. Taylor).

Overgrazing early in the spring can have significant repercussions ranging from stand loss, low vigor (and thus lower yields) for the remainder of the season, weed encroachment, and susceptible plants subject to damage from other seasonal stresses (temperature, moisture, insects, diseases, and weeds). Favorable growing conditions are not enough to overcome the damage done to these pastures that eventually may need partial or complete renovation to restore them to optimal productivity.

What options do you have when you are not set up for rotational grazing? As expensive as it may be to keep animals in the barn or on a sacrifice lot where you will have to provide them with hay or other feed, this remains your best and often only option. You need to keep animals off pastures until adequate growth has occurred. A rule-of-thumb suggests allowing pastures to obtain 2 inches of additional growth (above the suggested normal height) before the first grazing period for all forages. For example, Kentucky bluegrass, many clovers, and bermudagrass should be about 4 inches high when you begin grazing but for the first spring grazing cycle you should allow them to reach 6 inches before starting.

Another option available is to ensure the animals are well fed before they are let out onto the pasture. This works for ruminants but will not work as well if grazing horses. Horses with their small stomach tend to graze a large percentage of the time they are on pasture. To use this option with horses, you will need to limit the time they spend on the pasture to a few hours per day, lengthening the time as the grass approaches the suggested height for grazing. A second caution—if you have less than 2 to 3 acres available per horse, you are close to the point of overstocking the pasture and will need to be very careful not to over graze.

A third option partially discussed above is to limit the amount of time the animals are allowed to graze on a pasture in early spring. Depending on the growth rate of the pasture it can range from one or two hours per day to many hours per day. This is appropriate where a lack of interior fencing does not allow rotational grazing but the manager has time available to move animals between the barn or exercise/sacrifice lot and the pasture.

Legume-Associated Frothy Bloat in Cattle

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Bloat is a severe enlargement of the abdomen due to an over-accumulation of gasses trapped within the rumen. This condition can affect both sheep and cattle, although it is most common in the later. Bloat can be either frothy bloat or the less frequent free-gas bloat. The most common cause of frothy bloat in cattle is the consumption of bloat-causing legumes. To prevent losses from legume-associated frothy bloat in cattle, it is important to understand the symptoms of the condition, the causes, and treatments or preventative strategies that can be implemented for on-farm use.

In healthy cattle approximately 30 to 50 liters of gas are produced every hour. Gas is produced as a result of microbial fermentation of ingested feeds and it accumulates at the top of the rumen. Animals rid their bodies of this gas through belching. Belching should occur about once every minute if normal fermentation processes are occurring inside of the rumen.

Why does gas build up?

In frothy bloat, the belching mechanism fails to occur because gas becomes trapped in small bubbles. These bubbles form a frothy or foamy mass inside the rumen. Since gas is no longer in the free form, rumen receptors fail to recognize its presence. Without reflexive belching, gas has no means of escaping causing the rumen to inflate. The condition can first be spotted as a swelling on the left flank of the animal. Other early symptoms include standing up and lying back down repetitively, kicking at the belly, frequent defecation and urination, grunting, and extension of the neck and head. As bloat severity worsens animals have difficulty breathing because of pressure that is exerted on the diaphragm by the gas-filled rumen. In severe cases, rumen contractions can stop completely and a distinct drum sound can be heard if the rumen is tapped or flicked. This characteristic sound is the reason why bloat is often referred to as ruminal tympany.

Which legumes are bloat-safe or bloat-causing?

Consumption of legumes in large quantities is one of the primary causes of frothy bloat; however, not all legumes cause frothy bloat. Legumes can be classified as bloat-causing or bloat-safe. Bloat-causing legumes include alfalfa, sweetclover, red clover, ladino clover, white

clover, and alsike clover. Bloat-safe legumes include sainfoin, birdsfoot trefoil, cicer milkvetch, and lespedeza.

Why is one legume bloat-safe and another bloat-causing?

There are many ideas why certain legumes cause bloat and others do not. It seems that a combination of plant, animal, and microbial factors contribute to the risk of bloat. First, bloat-safe legumes have thick cell walls that prevent or reduce mechanical disruption (breaking plant cells open) while animals are chewing. This means that when bloat-safe legumes enter the rumen it will take longer for rumen microorganisms to invade plant tissues so they are digested very slowly.

Plant Factors: Plant cells from bloat-causing legumes are more likely to be broken down during chewing because of weaker cell walls. Rumen microorganisms have easier access to the cell contents. When cells from green leaves are broken open, one component that is released is chlorophyll contained in the chloroplasts of the cells. It is thought that the increase in chlorophyll and soluble protein concentration from broken chloroplasts (disk-like bodies packed with chlorophyll) in the rumen is the main cause of legume-associated bloat. The soluble proteins are believed to be the major foaming agents in the rumen.

In addition to stronger cell walls, bloat-safe legumes have large amounts of condensed tannins which inhibit frothy bloat. Condensed tannins are plant polyphenols capable of binding soluble proteins responsible for foam production. Condensed tannins have also been shown to reduce digestive activity of rumen microorganisms, slowing clearance of feed particles from the rumen. This can be beneficial since rapid passage of legume particles from the rumen has been linked with a higher incidence of bloat. However, tannins are only advantageous to a certain degree. If tannins reach concentrations in excess of 0.2 to 0.3 percent of dry matter intake, digestion can be negatively affected.

Microbial Factors: There are also microbial factors which contribute to the stability of foam inside the rumen. In bloated animals it has been noted that rumen bacteria produce an overabundance of mucopolysaccharides (sticky carbohydrates) that form slime in the rumen. This slime increases the thickness (viscosity) of rumen contents as well as stabilizing the gaseous foam. It is thought that the increase viscosity leads to formation of gas into the characteristic bubbles.

What can be done if bloat occurs?

Emergency Solutions: Frothy bloat can often be detected in as little as 30 minutes to 1 hour after animals have grazed on bloat-causing legumes. To properly treat animals the severity of the condition has to be accurately assessed. If the condition is severe, pressure inside of the rumen should be relieved immediately by a veterinarian if possible or by an incision through the skin into the rumen with later repair by the veterinarian.

Chemical Solutions: In animals showing less severe symptoms administration of an antifoaming agent is the most effective way to treat and prevent frothy bloat. Decreased salivation is one of

the key characteristics of the condition so saliva, although a natural antifoaming agent, is not able to control rumen froth. Producers can choose from a variety of other sources for antifoaming agents, the most common of which are oils, fats, synthetic non-ionic surfactants, and ionophore antibiotics. Depending on the product, treatments can be drenched into the rumen; sprayed onto pasture; added to feed, feed blocks, or water troughs; and applied to the flanks of animals. Dosages also vary depending on the product so read the label carefully. Animal fats, vegetable oil, and mineral oil are all work equally well in the rumen. The most common non-ionic surfactant used on the market is poloxalene. Surfactants can be applied in smaller quantities compared to oils and fats, which is an advantage for producers. It is thought that non-ionic surfactants work by reallocating dietary lipids (fats) in the rumen, allowing them to become more successful anti-foaming agents.

Ionophore antibiotics, like monensin and lasalocid have both been used for treatment of frothy bloat. It is thought that these products reduce bloat by inhibiting the growth of bloat-causing microbes and also possibly by altering ruminal volatile fatty acid (VFA) production. They are able to convert acetic acid to propionic acid, thereby reducing the amount of methane and CO_2 gas produced in the rumen.

Animal and Pasture Management Solutions

There are many preventative management strategies that can be used on-farm to lessen the incidence of bloat when feeding legume forages. First, the stage of plant growth should be monitored since, the likelihood of bloat decreases with advancing maturity. Plants in the pre-bud stage are the most bloat-prone, so grazing should be kept to a minimum at this time point. One of the most beneficial management strategies is seeding a mixed sward, with at least 50% of the total plant population being grass. Animals grazing legume to grass forage in a 50:50 ratio consume about equal quantities of both forages, thus preventing bloat. This technique assumes that animals are not displaying selective feeding behavior in the field.

Other preventative strategies include feeding coarse, long-stem hay prior to grazing bloat-prone legumes, cutting and wilting forage prior to grazing (rotational grazing systems), and avoiding discontinuous grazing of legumes. Animals also are thought to be more susceptible to bloat if allowed to graze legumes in the early morning while due remains on the legumes leaves. Limiting grazing time on immature legume pastures and introducing animals that have already fed can help reduce the risk of bloat. Some animals are more susceptible than others so where legumes are a part of a grazing rotation and there is a chance to cull animals, cull those that show susceptibility to bloat. In the long-term, this will reduce the herd's susceptibility to bloat. Whenever introducing ruminant animals to a new legume-containing pasture, the manager should observe animals frequently during the first few weeks of grazing to lessen the risk of losing animals to bloat.

The Role of Nutrition and Metabolic Controls in Subfertility of Lactating Dairy Cattle

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Lactation demands interact with energy and nutrient intake and genotypic makeup erode function in the reproduction system of the modern dairy cow. Genetically driven high lactation yields require high dietary dry matter intakes (DMI) to support the energy demands partitioned by metabolic events to meet maintenance, lactation and reproduction needs in cattle. Often events governing nutrient partitioning and utilization secondarily result in sub-fertility. Indeed, infertility is a progressive problem in modern dairy cows.

Historically, producers established breeding and selection programs based on increased milk yields. The resultant high milk yields have in themselves generated a number of managerial, nutrient partitioning, metabolic (gluconeogenic, insulin resistance and IGF), environmental, and nutrient utilization issues that directly impact fertility. Many of the metabolic and nutrient partitioning issues have probably arisen because selection for high milk yields has indirectly or directly selected for physiologic and metabolic processes that direct nutrients towards milk production at the expense of the needs of reproductive performance. The process may therefore feed on itself in that increasing DMI drives milk production that only serves to further deprive reproductive function.

An admirable goal for the future is to provide nutritional strategies with rations that enable nutrient partitioning for attaining and sustaining pregnancies while supporting high milk yields. These strategies need optimize physiologic and endocrinologic aspects of uterine health, uterine and endometrial function, endocrinologic function of the hypothalamic and pituitary glands, ovarian health, folliculogenisis, follicle welfare, corpus luteal health, and finally luteal regression.

Body condition score (BCS), nutrient signals and subfertility

Management of body energy and protein reserves (fat and muscle tissue loss) is an important component of lactation cow management. The best practical indicator of body energy and protein reserves is still the BCS. Sub-fertility and infertility are associated with BCS that are too low or too high. Cows that are too thin simply do not have the energy reserve to simultaneously support lactation demands along side reproductive function. The relationship between pre-calving weight and BCS loss is high (r^2=0.82). The heavier the cow, the greater the loss in body condition during the postpartum period when DMI cannot meet lactation needs. Fatter cows also tend to lose more body weight than thinner cows during heavy lactation simply because fat cows cannot maintain sufficient DMI under heavy lactation stress. Reproductive function takes a hit through the length as well as the depth of depressed pre- and post partum DMI. BCS or changes in BCS have the greatest impact on fertility at calving, at the nadir in BCS (usually at peak lactation) and then at breeding usually at some point after BCS nadir. Evaluation of BCS always

requires a careful, experienced assessment because cows with higher milk yields will always lose more condition while increasing DMI. High DMI in heavy lactating cattle can lead to gut fill that could be misinterpreted as higher BCS rather than tissue mass. BCS is a reasonable and practical (though subjective) estimate of body energy stores because BCS is highly correlated to fat stores (r^2=0.82). Higher (but not obese) BCS signify higher stores of body energy which are correlated with higher fertility. Higher, prepartum energy stores (but not obesity) directly impact DIM to first estrus and the probability of earlier pregnancy. Low BCS any time in lactation is associated with delayed ovarian follicular development and disturbances in secretion of hormones (estrogen, GnRH, and LH) involved in folliculogeneisis. Low BCS is associated with poor or no response of follicles to hormones orchestrating growth, ovulation, luteinization, and steroidogenisis. Any or all of these problems lead to infertility.

In addition to the detrimental affect of obese BCS on fertility, producers should also be aware animals with low body BCS many weeks prior to calving generally develop prolonged post partum anestrus intervals. Prolonged post partum anestrus occurs even when after cattle (with low BDS pre-partum) are placed on good diets after calving. Thus, excessively thin cows pre-partum extends days open until confirmed pregnant afterwards. It has been understood for many years that metabolic events today can have reproductive ramifications as long as 4-5 months later. The effect is termed follicle imprinting and occurs because ovarian follicles require 4-5 months of development and growth before generating an ovulatory follicle. Clearly, nutritional schemes and metabolic events in the preceding lactation, dry period, transition period and post parturient period impact follicle and oocytes health or welfare. There is no question nutrient and ration management prior to parturition will have negative effects extending far beyond the period of ration, feed bunk and nutrient mismanagement. Reproductive efficiency after the voluntary wait period can be seriously disrupted by pre-partum feeding programs.

Factors regulating BCS profile and subfertility: Shape of the ideal BCS curve is dependent upon several factors. The first are the genetic determinants of an animals target BCS. As producers are fully aware, some cattle experience great difficulty maintaining condition as other herd mates in the same lot and consuming the same ration become obese. The second factor is an individual cow's ability to assimilate or partition nutrients to meet maintenance, reproductive, and milk production needs. Lastly, there appears to be genetic differences between individual feed efficiencies. Genetic selection for milk yield has favored those animals that lower BCS early in lactation and then regain BCS later in lactation. These animals essentially partition nutrients toward lactation early after calving and thereafter repartition energy toward rebuilding energy reserves and body condition later in lactation. The ability of animals to accomplish these partitioning effects is partly driven by signal metabolites and hormones such as somatotropin (growth) hormone, insulin, leptin, and insulin-like growth factor. These regulators of metabolism align along an axis referred to as the somatotropic (growth hormone) axis. This axis and its mediators cross over to a second axis that regulates follicle growth and ovulation. This is the gonadotropin axis. The cross or spill over between the somatotropic system regulating nutrient intake, energy balance and DMI and the gonadotropic system regulating follicle growth and ovulation is how nutrition and metabolic events impact fertility.

Specific nutrient effects: Many different nutrients impact fertility including fats, starch, protein, minerals and vitamins. The preponderance (but not all) of data suggests supplementing

diets with fats (to a level ≤ 6% dietary DM) helps fertility. Starch supplementation can shorten days to first estrus and improve conception rates by enhancing blood levels of hormones (insulin, IGF) and metabolites (glucose) stimulating follicle growth and development and reducing the nadir of BCS loss during heavy lactation. However, high starch levels may hinder oocytes quality and negatively impact conception rates. Excessive soluble proteins (particularly rumen degradable proteins) like starch can deteriorate oocyte quality

How does all this work to impact fertility? Metabolic signals and reproduction

It is informative to spend some time exploring how metabolic, physiologic and endocrinologic responses to nutritional events in dairy cattle influence reproductive performance. Much of the impact is generated by hormones with a primary role in regulating nutrient partitioning that also have secondary effects on control mechanisms in reproductive function. Although these systems and their interaction remain poorly understood in dairy cattle, they function in linking reproductive performance to feed intake, body condition, and metabolic events driving lactation. Some of the key mediators of these links are growth hormone (BST), gonadotropin releasing hormone (GnRH), insulin, insulin-like growth factor, and leptin (see below).

Growth hormone may be the principle coordinator of metabolic events impacting nutrient metabolism and reproductive function. Growth hormone can trigger hormone (e.g. insulin, insulin like growth factor (IGF), and leptin) and metabolite [glucose and nonesterified free fatty acids (NEFA)] release from liver, pancreas, fat, and muscle tissues. These can feedback to centers in the brain, ovarian structures (follicles), and embryos in the uterus to affect DMI, secretion of reproductive hormones (GnRH, LH and estrogen), folliculogenisis, ovulation, and pregnancy. For example, GH and NEFA can both depress glucose uptake by reproductive organs while enhancing uptake by the mammary gland. This function shunts glucose away from reproductive organs and passes glucose to the mammary gland for lactation. This so called state of insulin resistance in lactating cattle is a great example of how lactation responses up-regulated by endocrinologic control mechanisms of metabolism drive milk production in the mammary gland to the detriment of ovarian and uterine functions. At the same time, insulin and IGF act directly on the uterus, ovary, and fetus to increase follicular sensitivity to hormones driving folliculogenisis, ovulation, corpus luteum function. Fetal growth and development are greatly impacted by IGF.

Recently, increased liver metabolism associated with the metabolic demands of lactation has been shown to have the bystander effect of enhancing breakdown and clearance of estrogen and progesterone from the blood of heavily lactating cows. As a result high producing cows have low estrogen and progesterone blood levels. Thus, high DMI associated with high lactation demands decrease the very steroid that drives strong estrus behavior and follicular ovulation (pre-ovulatory LH surge). Moreover, the high DMI may serve to drop progesterone levels sufficiently to interfere with fertility and maintenance of pregnancy.

When DMI intake in lactation stressed cows is reduced by heath problems [metritis, mastitis, retained placenta, subacute rumen acidosis (SARA), feed bunk competition or lameness], the loss in appetite and feed intake increases GH levels. Increased GH could possibly impact

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reproductive centers in the brain directly or indirectly (insulin, leptin, IGF secretion) and alter reproductive efficiency.

Hormone driven communication between metabolic systems controlling lactation and reproductive function can alter folliculogenisis, ovulation, corpus luteal growth and functions, estrus behavior, and pregnancy. GH appears to be an important mediator of the two way communication between metabolic and reproductive control mechanism. In the past, processes like folliculogenisis, ovulation corpus luteal function, and embryonic growth were though to be mostly impacted by reproductive hormones like GnRH, FSH, LH, estrogen and progesterone. Now, it is becoming very evident that hormones and metabolites of intermediary metabolism also directly impact many of these reproductive functions. Hormones like insulin, insulin-like growth factor (IGF). and leptin effect follicle cell growth, follicle cell responses to hormones driving follicle development, ovulation, as well as estrogen production in both small and large pre-ovulatory follicles. Even development of the oocytes during follicle growth is not immune to influences from metabolic events. Dietary effects on glucose levels or IGF activity in follicles directly impacts oocytes development prior to ovulation. Poor quality oocytes lead to slow or delayed embryonic growth and development. This can, in turn, lead to early embryonic death. Follicle growth and responses are also directly impacted by nutritionally driven changes in peripheral blood levels of insulin, IGF and leptin. For example, leptin, a hormone secreted by fat tissues during periods of weight loss can directly diminish estrogen synthesis and secretion by large pre-ovulatory follicles. Leptin production during loss of body condition could impact the strength of estrus, success or lack of success in follicle ovulation, and preparation of the uterine environment for embryonic growth and development.

Direct Effects of nutrition and metabolism on hormonal and ovarian follicle growth

Principles of follicle growth every producer should understand: Follicle growth in cattle always occurs in distinct waves of two-three hundred follicles per wave. Follicle waves start growing every three to four days. Therefore, an ovary will have at any time, 8-10 different waves of follicles under development. Follicle wave growth occurs during normal periods of cyclicity as well as in periods of anestrus (post partum). These waves all require the hormone follicle stimulating hormone (FSH) and luteinizing hormone that are secreted throughout the cycle at various levels. Follicles in each wave grow at the same rate until shortly before estrus at which time the wave produces a single ovulatory follicle. About 6-8 days before estrus, most of the follicles in a wave stop growing and deteriorate leaving one remaining follicle to dominate the growth. That follicle (if conditions are correct) becomes a potent source of estrogen and secretes all the estrogen that drives estrus (heat) behavior in the heat. At the same time, that estrogen signals ovulation of the dominant follicle. *Indeed, the dominant follicle (if conditions are correct) signals its own ovulation by triggering what is termed the pre-ovulatory surge of GnRH and LH.* Estrogen secreted by the dominant follicle triggers massive GnRH release from the cow's brain. This burst of GnRH is the same burst of GnRH producers create when they utilize GnRH injections in TAI programs to trigger ovulation. These dominant follicles also contain a high amount of insulin like growth factor (IGF) that aids FSH in driving follicle growth and estrogen secretion by the dominant follicle. All other follicles in the wave that deteriorate, do so in association with low levels of free IGF, an inability to respond to FSH and low levels of estrogen production. Each wave of follicle growth has a life span of approximately 10 days

before it must ovulate a follicle or regress into complete destruction. A majority (90-95%) of cows therefore have two follicle waves per 21 day cycle with a few showing 3-4 waves per cycle.

Effect of nutrition on follicle growth and development and follicle wave dynamics

Initially chronic negative energy balance from feed restriction over about 5 weeks *gradually decreases the size and growth rates of dominant (ovulatory) follicles even though ovulation will still occur.* Eventually injury to the dominant follicle results in the onset of anestrus. This could be called *nutritional anestrus*.

Time interval for the onset of nutritional anestrus: The interval from the onset of negative energy balance to the onset of anestrus is inversely related to the rate of weight loss. Cows losing 1.0 pound body weight/day will become anestrus 30-50 days earlier than cows losing 0.5 pound of weight/day. However, the time period ranges between 90, 175, and 224 days for cows losing 1.6, 1.0, and 0.8 pound body weight per day, respectively. Anestrus will inevitably occur in cows that have lost 22-24% of total body weight. These, of course, are animals in prolonged negative energy balance. *Even though these animals are anestrus, follicle waves growth and follicle development continues at regular 3-4 day intervals. The problem is the dominant follicle generated in these waves no longer generatse sufficient estrogen to drive strong heat (estrus) behavior.* Eventually the dominant follicles stop ovulating under these conditions.

Long term negative energy balance from voluntary or involuntary nutritional restriction leads to a linear decrease in size of the corpus luteum with decreasing body weight. This likely has a very significant impact on embryonic survival and onset of early embryonic death (EED) in weight loss animals.

Re-institution of follicle wave growth, development and dynamics following weight gains: As positive energy balance resumes and animals regain weight lost during the period of negative energy balance, the rate and size of follicle growth increases until ovulation resumes. However, ovulation may not resume until 6 or more estrus cycles have occurred.

Time interval for the onset of nutritional anestrus in post partum dairy cattle. Nutrition and ovarian follicle function during the post partum period: Post partum follicle growth resume by 10 days post calving. Cows will not delay the onset of post partum estrus if dominant follicles that emerge early in the post partum period go on to ovulate. Prolonged post partum anestrus results from a lack of dominant follicle ovulation rather than a lack of follicle wave growth post partum. Cows that develop anovulatory follicles lacking estrogen secretion in the first post partum wave of follicle growth delay estrus onset for up to 50 days post partum. In contrast, cows developing ovulatory follicles even in the face of no or weak heats in the first post partum wave delayed the onset of estrus just 20 days. About half of the post partum cows ovulate follicles in the first post partum wave of follicle growth suggesting nearly half of post partum cows will experience post partum delay in the onset of estrus.

Thus the association between negative energy balance and delayed post partum estrus most likely results from disruption of dominant follicle ovulation early post partum. Follicle growth

or even dominant follicle formation per se does not appear to be impacted by negative energy balance through 25-30 days of early lactation. Clearly, the follicles are present but simply unable to ovulate. Dominant follicles emerging in later waves post partum when the nadir in negative energy balance has passed will go on to ovulate again.

Mechanisms of nutritional anestrus and disrupted follicular dynamics

Producers should note no data exists to show any specific macro-or micronutrient deficit will create reproductive problems. Nutrient problems driving infertility and subfertility all relate to the same components of a nutrition program designed to meet lactation and maintenance needs of the dairy cow. Producers should at least be aware that the mechanisms of governing digestion, metabolism and nutrient partitioning in lactating cattle also impact ovarian follicular growth, development and ovulation. Knowing events regulating nutrient assembly and partitioning also regulate folliculogenisis and fertility should drive producers to pay closer attention to ration composition, ration preparation, feed bunk management practices, and cow comfort throughout the productive lifetime of the cow. Mistakes, inattentiveness or carelessness in these areas may alter mechanisms of nutrient assembly and partitioning with secondary deleterious consequences for fertility. A brief look at possible mechanisms through which nutrition can impact ovarian function is helpful.

Failure of ovulation and nutrition

Ovulation failure and loss of estrogen synthesis in negative energy balance: Ovulation failure is one of the greatest reproductive problems with significant consequences for onset of first estrus in the post partum period. Normally, ovulation has an absolute requirement for estrogen. *Adequate follicle health and growth 7-8 days prior to heat leads to increasing blood levels of estrogen that drive strong estrus behavior and timely follicle ovulation at the end of estrus. The follicle secreting this estrogen is also the follicle that will ovulate at the end of estrus (heat).* ***Two to three weeks of negative energy balance can eventually lead to reduced estrogen secretion by developing follicles. Low estrogen production particularly 2-3 days prior to estrus will result in ovulation failure.*** In many of these cases, the ultimate reason for ovulation failure is a lack of an estrogen induced GnRH secretion from the brain. It appears centers in the brain responsible for GnRH secretion do not function well during negative energy losses. Typically, these cows are losing weight and body condition, show weak or no heats, and then fail to ovulate. Conditions generating these hormonal problems can develop within 2 cycles (40 days) and are due to deterioration in hormone secretion (GnRH and LH) that drives follicular estrogen production as follicles grow 3-5 days prior to heat. These problems may develop after a 15 percent loss in weight.

Ovulation failure and lowered insulin levels in negative energy balance: Negative energy balance lowers circulating insulin blood levels in cattle (Figure 1). Lower insulin levels may actually be a key event that desensitizes growing follicles to hormones (LH) driving estrogen production in the 3-5 days before estrus. The desensitization appears to occur at the follicle itself. Thus, follicle waves generating dominant follicles larger follicles that cannot produce estrogen contribute to weak heats, anestrus and/or failure of ovulation.

GnRH from Brain Center

GHRH from Brain Center

Elevated DMI

FSH and LH from Brain

Growth Hormone from Brain

GH

Follicle Growth and Ovulation

GH
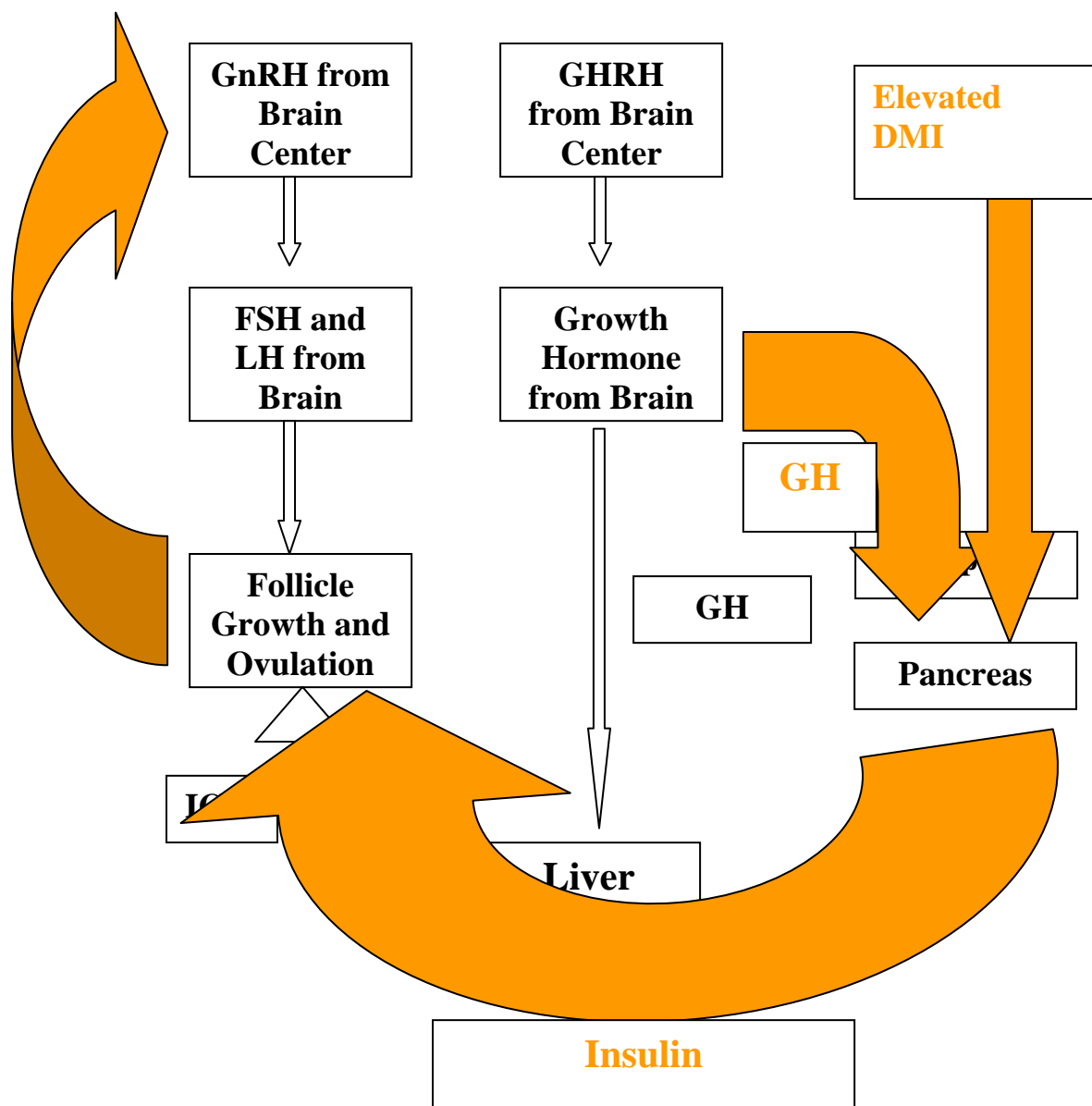
Pancreas

IGF

Liver

Insulin

Figure 1. Increased DMI and (or in association with) increased growth hormone production in cows may increase circulating insulin levels in the blood. Insulin acts locally on follicles to enhance growth, estrogen production and LH sensitivity to enhance ovulation.

Ovulation failure and lowered insulin like growth factor-1 levels (IGF-1) in negative energy balance: Negative energy balance, loss of body condition is also associated with lower circulating levels of insulin like growth factor (Figure 2). Lowered dry matter intake **(DMI)** is associated with linear decreases in circulating IGF-1 up to the point of ovulation failure. Reversal of lower DMI is associated with linear increases in circulating levels of IGF-1 up until there is a resumption of dominant follicle ovulation. This factor must accumulate in follicles during the 3-5 day period of dominant follicle development before estrus as follicular IGF-1

levels are directly related to circulating blood levels of IGF-1. Lowered blood levels limit follicular accumulation of IGF-1. IGF-1 functions very similar to insulin in follicles by increasing follicle sensitivity to LH stimulation and driving follicular growth. Therefore IGF-1, like insulin, ultimately affects estrogen production. The dominant follicle provided it produces sufficient estrogen will drive strong heats and ovulation. Again, ovulation is orchestrated by estrogen mediated GnRH and LH secretion from the brain. In the face of lowered IGF-1 and insulin, dominant follicles do not grow well but certainly cannot synthesize and secrete estrogen. This leads to weak heats and failure of ovulation. Delays in recovery of positive energy balance post partum are responsible for delays in first post partum estrus and the delay in recovery of circulating IGF-1 levels.
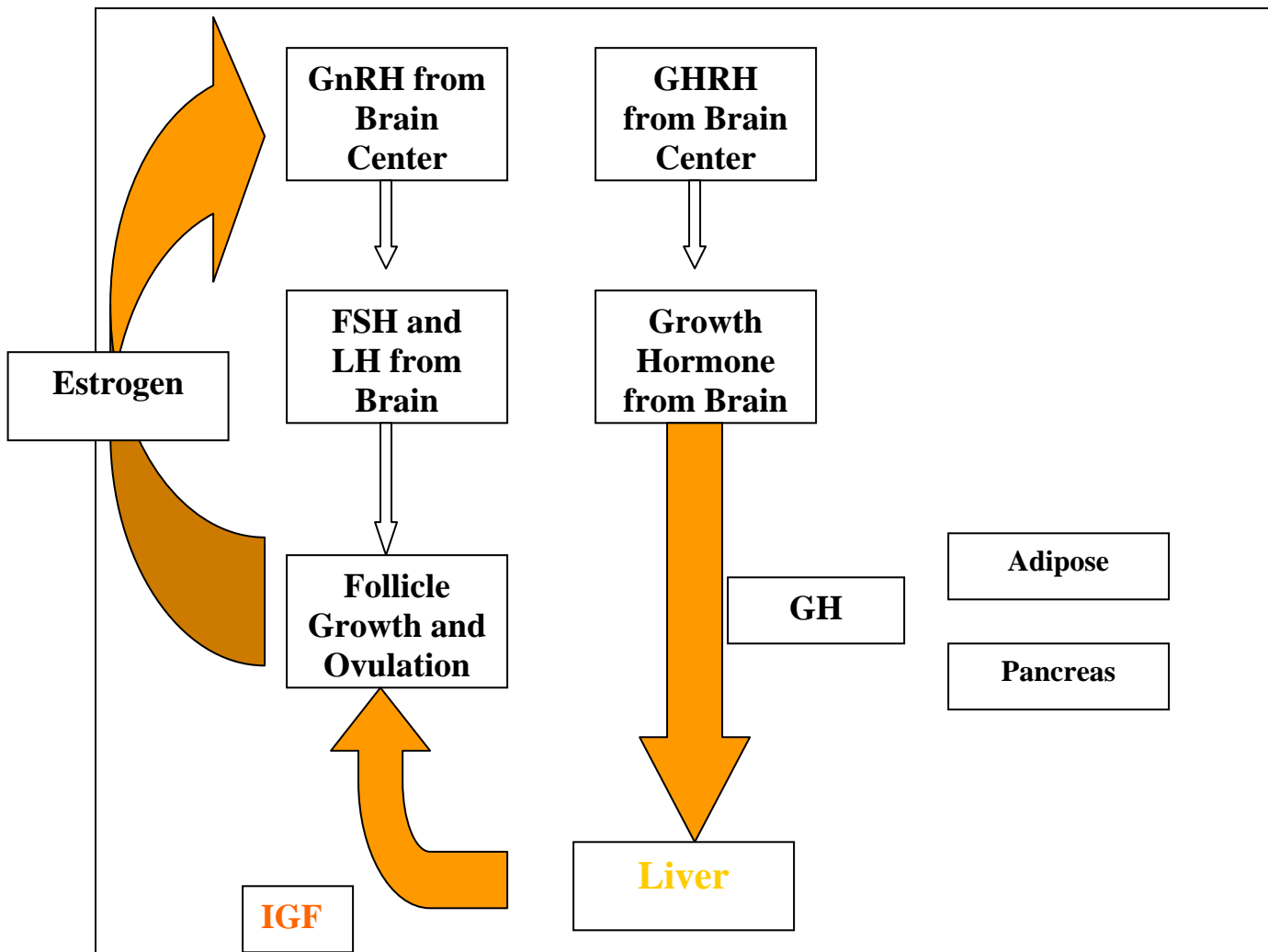
Figure 2. Increased growth hormone secretion that accompanies increased DMI affects the mechanisms regulating reproductive function primarily by driving hepatic production of insulin like growth factor 1.

Ovulation failure and lowered blood glucose in negative energy balance: Blood glucose is also an extremely important metabolic regulator of reproductive function (Figure 3.). Negative energy balance in the face of heavy lactation demands is associated with lower circulating levels

of blood glucose. Lowered blood glucose directly impacts reproductive function by inhibiting the brain centers responsible for release of GnRH. The inhibition can manifest itself as complete absence of GnRH secretion or delayed GnRH secretion. Again, this is the same GnRH producers administer during TAI programs to trigger ovulation. Thus, lowered blood glucose during the nadir in BCS scores impairs or delays the pre-ovulatory release of GnRH that triggers dominant follicle ovulation at estrus. Thus, even if follicle growth and estrogen production was adequate during the 3-5 day period prior to estrus, cows arrive at estrus showing strong heats but are subfertile. The adequate levels of estrogen should stimulate ovulatory GnRH responses but now the brain is unable to respond to estrogen because of low blood sugar. In the end, these cows might show strong heats at estrus but be completely anovulatory or minimally delayed ovulators at the end of heat. Problems in insulin, IGF-1, and estrogen induced ovulation become further compounded by low blood glucose.

GnRH from Brain Center

GHRH from Brain Center

Elevated Concentrate in DMI

FSH LH Br

Growth Hormone from Brain

Follicle Growth and Ovulation

ose

Pancreas

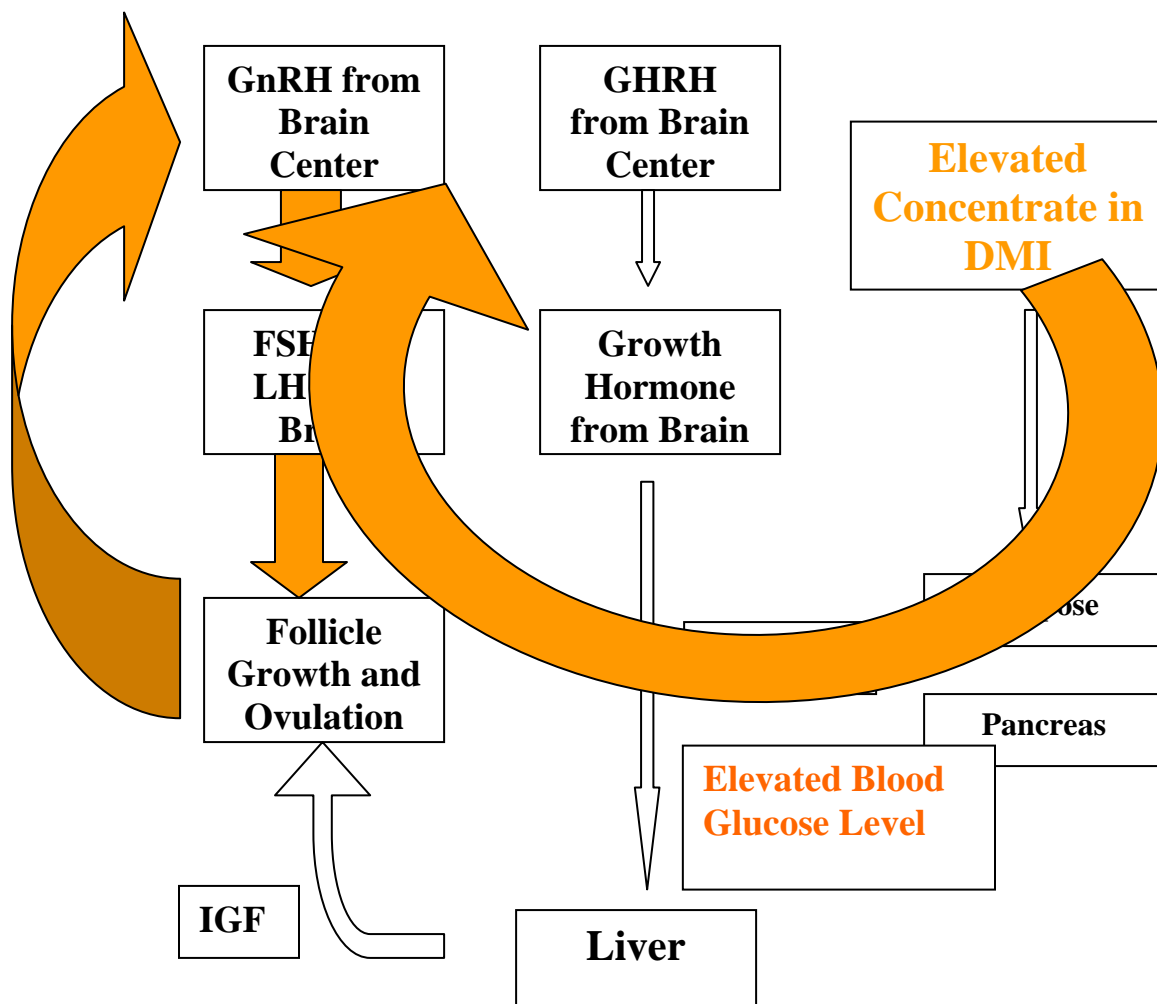Elevated Blood Glucose Level

IGF

Liver

Figure 3. Increased DMI with higher concentrate:forage ratios increases blood glucose levels. Higher blood glucose acts on the brain to drive increased GnRH release that triggers follicle growth and ovulation.

Ovulation failure, negative energy balance and leptin in dairy cattle: Leptin is a hormone generated by fat tissue and functions as a mediator of appetite cues with secondary" bystander"

effects on the reproductive system (Figure 4). Typically as fat tissues become engorged with energy stores (fat), leptin levels rise and depress appetite. Fat cows generally show higher levels of circulating leptin than thinner cows and cows in negative energy balance tend to have depressed levels of leptin. Leptin levels are generally controlled by fat content and DMI in cattle. Normally, leptin levels decline early in lactation as negative energy balance drains fat tissue energy stores. Leptin levels hit a nadir during the nadir in BCS and then climb toward normal about the time of the first post partum ovulation. Circulating leptin levels tend to be positively correlated with circulating levels of insulin, glucose, and IGF-1.
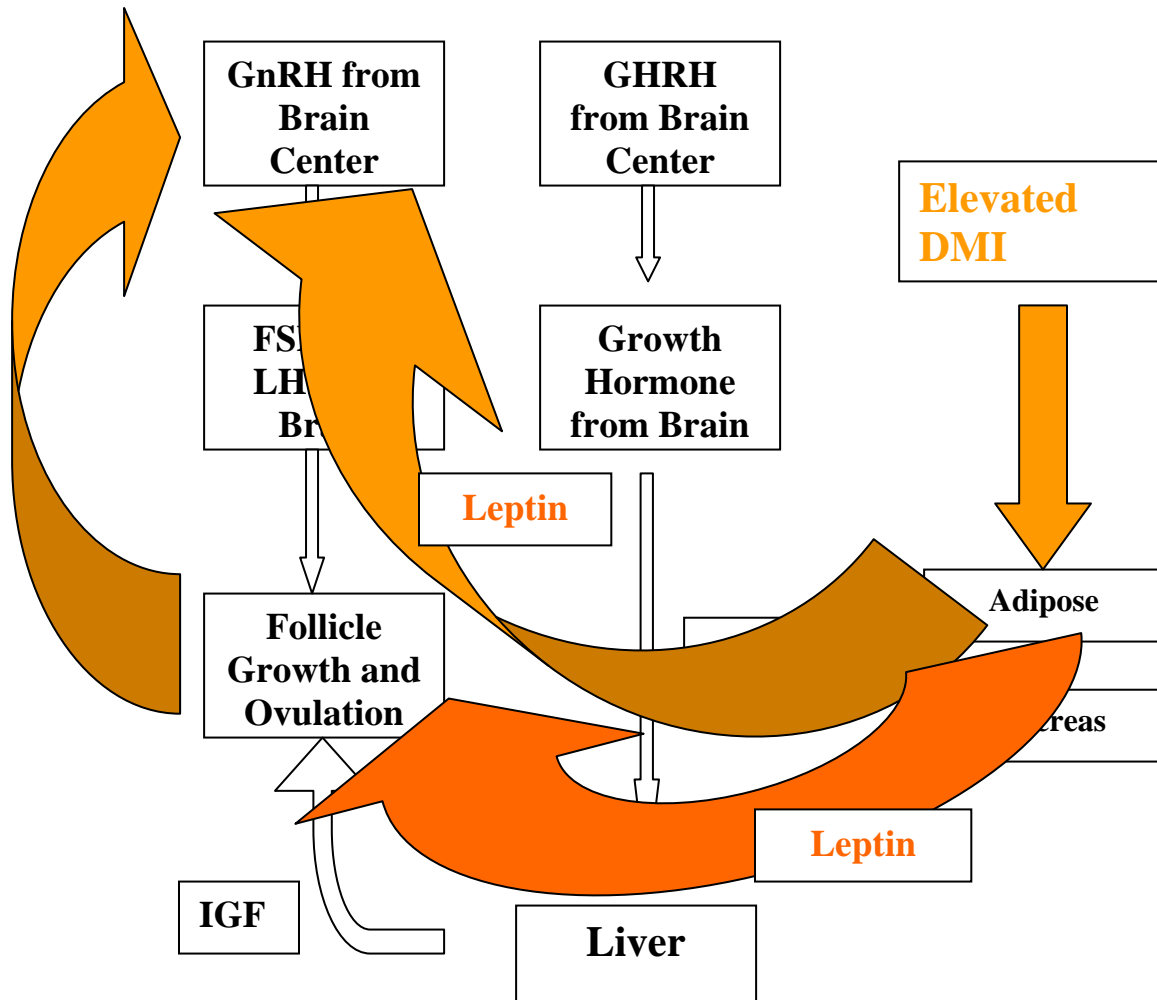

Figure 4. Leptin is released by fat tissue as fat deposition occurs with increased DMI and positive energy balance. Leptin secretion from fat tends to support GnRH secretion by brain centers controlling reproduction. This enhances follicle growth, estrogen production, and ovulation.

Lowered leptin (during loss of fat in negative energy balance), like lowered blood glucose, also appears to impair brain centers responsible for release of GnRH and inhibits ovulatory levels of GnRH secretion during estrus. In fact, ovulatory GnRH and LH activity is inhibited along side the nadir in circulating leptin levels during post partum in lactating cattle. Delays in recovery of positive energy balance post partum are responsible for delays in first post partum estrus and

correlated with the delay in recovery of circulating leptin levels. Thus, there is a very strong relationship between energy balance, BCS, leptin levels, and fertility.

Genetic markers of metabolic and reproductive function: The future in genetic selection and breeding programs? Earlier it was stated that many metabolic, nutrient partitioning, and utilization issues impacting fertility have probably arisen because selection for high milk yields has indirectly or directly selected for physiologic and metabolic processes that partition nutrient utilization more towards milk production at the expense of the needs of reproductive performance. This possibility raises the concern that high lactation qualities are mutually exclusive of high fertility qualities in the same dairy cow. Recent information on leptin genetics, may prove to be the path producers can follow to acquire these two very desirable traits in the same cow. Early data suggests at least 14 genetic variants of leptin exist in dairy cattle. Some of the variants were weakly associated with more sustained levels of circulating leptin than other variants. Three variants were also weakly associated with low days to first post partum estrus and post partum luteal activity. It is not known whether the specific variations in leptin gene structure were causal or linked to other genes affecting these dairy traits but these types of production markers may become powerful selection tools for planning future breeding programs. Sire selection based on genetic production markers could help incorporate high production traits into the same dairy phenotype with high fertility.

Conclusions

Diets that enhance glucose, insulin, and IGF1 levels in the blood likely will promote ovulation early after parturition. These type of diets increase insulin, glucose, and IGF1 levels in dominant follicles approaching ovulation. High intra-follicular insulin, glucose, and IGF1 will drive steroidogenisis and estrogen production which through its effect on secretion of GnRH will promote dominant follicle ovulation. These cows will show strong ovulatory estrus and ovulate early in the post partum period. Producers should also be aware that under normal lactation stress producing moderate changes in BCS, fertility improves with each consecutive estrus for 3-4 cycles. Delays in estrus onset can then have serious repercussions in days open. Cows with delayed post partum first estrus may accrue an additional 40-50-days open. At a cost of $1.30-$1.40/day/cow, pre-and post partum nutritional errors generating delays in post partum first estrus can become costly. Diets driving high insulin, IGF1, and glucose responses tend to be relatively high in concentrate to forage ratios and can help drive reproductive function but can also lead to subacute rumen acidosis (SARA) and diminished DMI. A producer's ability to reduce negative energy balance and nadirs in BCS during early lactation is very dependent upon skills in forage production, ration preparation, feed bunk, and feed program management.

In the absence of individual levels of dry matter intake, energy status in the lactating cow is difficult to directly measure. Some measures of energy balance include milk fats early in lactation (first few days), milk protein within the first 2-3 test dates and BCS. Milk fat is difficult to use because moist first test dates are after the first few days of lactation. Low milk proteins early in lactation can indicate significant negative energy balance in lactating cattle as lower milk proteins are associated with negative energy balance.

Perhaps the easiest tool is body condition scores. Typically scores range from 1-5 with 1 indicative of extremely thin and 5 extremely obese body condition. Theoretically, cows should not drop more than a half to three fourths body condition score over the first 30-40 days of lactation. This is equivalent to losing between 60 and 90 lbs of body weight. Any greater loss signifies very serious deficits in energy balance and will result in delayed first post partum estrus, weak estrus, anestrus, increased days open, and reduced conception rates.

References

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Notices and Upcoming Events

March 19, 2008
New Castle County Crops Meeting, Blackbird, DE. Contact Anna Stoops at 302-831-8860 or email: stoops@udel.edu

March 20, 2008
Organics 101: An Introduction to Organic Crop Production, Wooster, OH. Contact Kathy Bielek, OARDC, at (330) 202-3528, or email: bielek.4@osu.edu; or Mike Anderson, OEFFA, at (614) 421-2022, or email: mike@oeffa.org

April 12, 2008
Nutritional Management of Horses, Dover, DE. Contact Susan Garey at 302-730-4000 or email: truehart@udel.edu

November 18-20, 2008
Mid-Atlantic Crop Management School to be held at the Princess Royale Hotel and Conference Center in Ocean City, Maryland. Contact Dr. Greg Binford (email: binfordg@udel.edu) with questions or to obtain a registration booklet (available sometime in late August).

Newsletter Web Address

The Regional Agronomist Newsletter is posted on several web sites. Among these are the following locations:

http://www.grains.cses.vt.edu/grains/Articles/articles.htm

or

www.mdcrops.umd.edu   Click on Newsletter

Photographs for Newsletter Cover

To view more of Todd White's Bucks County photographs, please visit the following web site:

www.scenicbuckscounty.com