HARVEST STAGE EFFECTS ON YIELD AND QUALITY OF WINTER FORAGE

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ABSTRACT

Cereal forages are an important component of dairy rations. These small grain forages are versatile, economical sources of digestible fiber, protein and minerals. Numerous studies in California have documented differences in yield and feeding value of winter cereals at four distinct stages of maturity: boot, flower, milk and soft dough. A recent investigation tracked *in vitro* digestibility of three species of small grains at 5-day intervals from pre-boot to hard dough stage of maturity. Data from this study support findings of previous work and provide a detailed picture of quality changes occurring over a wide range of plant development.

Key words: winter forage, small grains forage, cereal forage, forage quality

INTRODUCTION

Small grain cereals (wheat, barley, oats, rye and triticale) are important forages in California. Within each of the main forage species are many varied cultivars which have unique agronomic characteristics. It is estimated that about 400,000 acres of small grain forages were harvested as silage, hay or green chop in California during 2000 (1). These crops are typically planted in November and December and harvested in April or May. Small grain winter forages fit well in double cropping systems with corn silage. Together, the corn and winter forage crops recycle manure nutrients and water from the dairy, and provide an important source of economical feed all year long. In the San Joaquin Valley, wheat is the most common forage choice among dairy producers. Wheat is usually harvested at the soft dough stage of maturity and ensiled at 30-35% dry matter for use in dairy rations. Triticale has been gaining acceptance, while use of forage blends has declined. Barley, once widely planted for forage, has suffered disease problems in recent years and lost popularity. Oats are most often planted for hay or included as a component in a forage mix. In the intermountain regions of northern California, rye or other small grains can be planted in early fall for late fall and early spring grazing and for hay production (2). Small grain forages are also widely used in other parts of the western U.S. (3).

CHARACTERISTICS OF SMALL GRAIN FORAGES

Four distinct growth stages of small grains are generally recognized for harvest:

- **Boot –** This is the stage just prior to heading out. The flag leaf is fully expanded, but the awns and grain head are not visible. The grain head can be felt in the flag leaf sheath. Boot stage usually begins in late March or early April depending on cultivar, and it lasts for about a week to ten days.

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- **Flower –** At this stage, the grain head and supporting stem have emerged from the flag leaf sheath. The plant has completed vegetative growth and entered the reproductive stage. A close look at the head reveals anthers, the flower parts that shed pollen. If you shake the grain head into your hand, the yellow pollen may be visible. Flowering typically begins mid to late April and lasts about five to seven days.

- **Milk –** This is the stage when the grain kernels on the head begin to develop. A white, milky fluid appears when a kernel is squeezed between your thumb and forefinger. Milk stage lasts about ten days.

- **Soft Dough –** At this stage the kernel is well formed and filled with starch. When squeezed, there is no milky fluid, only a rubbery dough like substance. Soft dough stage lasts about a week to ten days.

There are tremendous differences in yield and feeding value of small grain forages depending on which growth stage is chosen for harvest. Numerous studies have been conducted to evaluate these differences (4-10). Based on results of these studies, the following generalizations can be made:

- Percent crude protein (CP) and digestibility are higher at the earlier, less mature growth stages

- Percent acid detergent fiber (ADF) and neutral detergent fiber (NDF) are higher at boot than at soft dough stage; digestibility of these constituents is also much higher at boot stage

- Percent non-structural carbohydrate (NSC) is lowest at the early growth stages and highest at soft dough

- Percent lignin is lowest at the early growth stages and highest at soft dough stage

- Dry matter yields are lowest at boot and highest at soft dough stage

- Depending on the type of feed needed, the best stage to harvest is either boot or soft dough

Dairy producers have long recognized the difference in feeding value of alfalfa harvested at bud stage compared with mid or full-bloom stage harvest. Quality testing programs for alfalfa have been in place for decades based on research that has shown greater digestibility, faster weight gains, and higher milk production from cattle fed alfalfa harvested at an immature stage. Maturity of alfalfa is closely related to its fiber content. As stage of maturity increases, so does its fiber content, and digestibility decreases. For alfalfa, there is a negative correlation of digestibility with fiber. Laboratories that test alfalfa hay predict TDN and energy from its fiber content. These values in turn are used to establish relative economic value of different lots of hay.

Small grain forages have certain features that are very different from alfalfa. The percentage of fiber does NOT increase with increasing maturity like it does in alfalfa. In fact, the fiber level is usually lower or about the same at soft dough as it is at boot stage. This is because as the plant matures, grain development contributes non-structural carbohydrates (starch) which dilute out the fiber component. Digestibility is greatest at immature stages when fiber levels are also highest. There is a positive correlation of digestibility with fiber, the opposite of the fiber and digestibility relationship we see in alfalfa. Energy prediction equations used for alfalfa can not be used to accurately describe TDN or energy value for small grain forages. Other methods have recently been developed which should predict the energy value of small grain forages more reliably. These methods involve *in vitro* digestion, a procedure in which samples of the forage are incubated with rumen fluid from a cow (11). Results of *in vitro* tests conducted on several small grain forages last season provide an interesting look at forage quality changes that occur with advancing plant maturity.

CHANGES IN NUTRITONAL VALUE OF SMALL GRAIN FORAGE WITH ADVANCING MATURITY

During the 2001 growing season, four small grain forages in the south San Joaquin Valley were sampled at five day intervals from pre-boot to hard dough stage of maturity. The forages included one cultivar of oats (Sierra), one cultivar of wheat (Bonus) and two cultivars of triticale (Trical 111 and Trical Castle). The forages were planted in 40' x 60'strips in a wheat field near Hanford, CA. Prior to sampling, development stages of the plants were noted using Zadok's scale of cereal grain development. The Zadok's scale is a numerical system that is used by plant breeders to describe plant development. It is more precise than the four general categories of boot, flower, milk and soft dough described above. The forage samples were analyzed at Dairy One Lab in New York for dry matter, CP, ADF, NDF, digestible NDF, NSC and *in vitro* total digestibility (IVTD). As stated above, the *in vitro* total digestibility is a laboratory test that simulates conditions in the digestive system of a cow to estimate digestibility of a feed.

The attributes of the forages sampled are as follows: Bonus wheat, Trical 111 triticale and Sierra oats are examples of early maturing winter forage. Trical Castle is a late maturing cultivar of triticale. Boot stage occurred in late March for the wheat, oats and Trical 111 triticale; and in mid-April for Trical Castle triticale. Soft dough stage occurred in mid-May for the wheat, oats and Trical 111 tritcale and early June for Trical Castle triticale.

The following charts show changes in CP, NSC, digestible NDF and IVTD with advancing maturity for two of the forages sampled. In each chart, the data point for each sampling is represented with a small diamond icon. A trend line through small square icons has also been included on the charts.

Changes in crude protein – Figures 1 and 2 clearly show the negative correlation of crude protein with advancing maturity. At the first sampling in early March, prior to boot stage, crude protein was greater than 25% for both the wheat and the triticale. By soft dough stage in mid to late May, crude protein had dropped to about 8% for the triticale, and to about 12% for the wheat.

Figure 1.

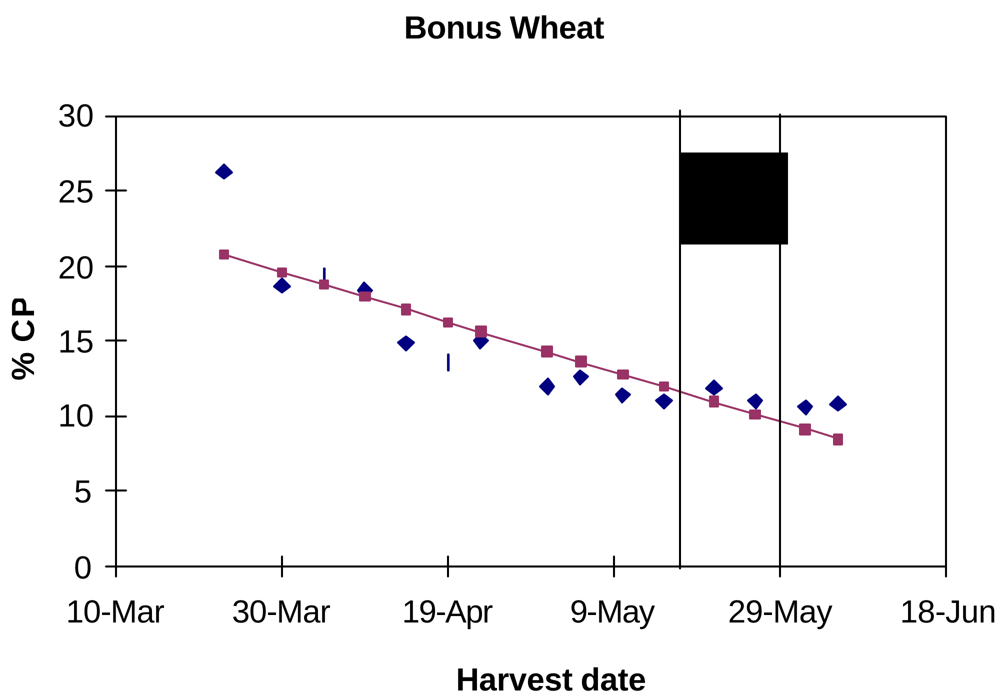
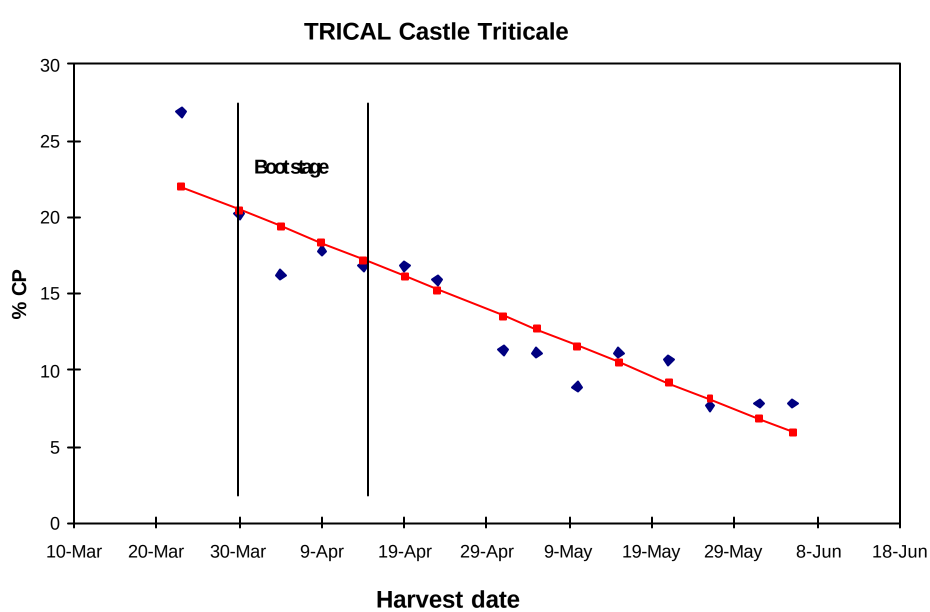


Figure 2.



Changes in non-structural carbohydrates: Plant sugars and starch are non-structural carbohydrates. Unlike cell wall carbohydrates which function to hold plants together, NSC serve as an energy source for plants. They are also a very digestible energy source for animals that consume the plants. Figures 3 and 4 show the relationship of NSC to plant maturity. When the plants are very immature, the NSC is in the form of plant sugars that serve as energy to fuel plant growth. Once the plants finish rapid vegetative growth and begin the reproductive stage, plant sugars are converted to starch and stored in the grain.

There is a positive correlation of NSC with advancing maturity although there are differences among cultivars. There is a big difference in the absolute levels of NSC between the wheat and the triticale. In the early growth stages the NSC is about 20% for the wheat and 15% for the triticale. By soft dough stage, NSC is 40% for the wheat and 23% for the triticale. This difference reflects the end use for which the plants were bred. Bonus wheat was developed for grain production. It is short in stature and produces high grain yields. Trical Castle was developed for forage production. It is a tall, leafy plant that is late maturing relative to the wheat. These two very different forages exemplify the diversity in small grains for forage. This particular culitvar of wheat is well suited to soft dough stage harvest because it can produce high yields of digestible grain to counter balance the high levels of indigestible fiber. The Trical Castle cultivar is best used for boot stage forage because of its unique feature of producing lots of very digestible vegetative growth prior to heading out.

Figure 3.

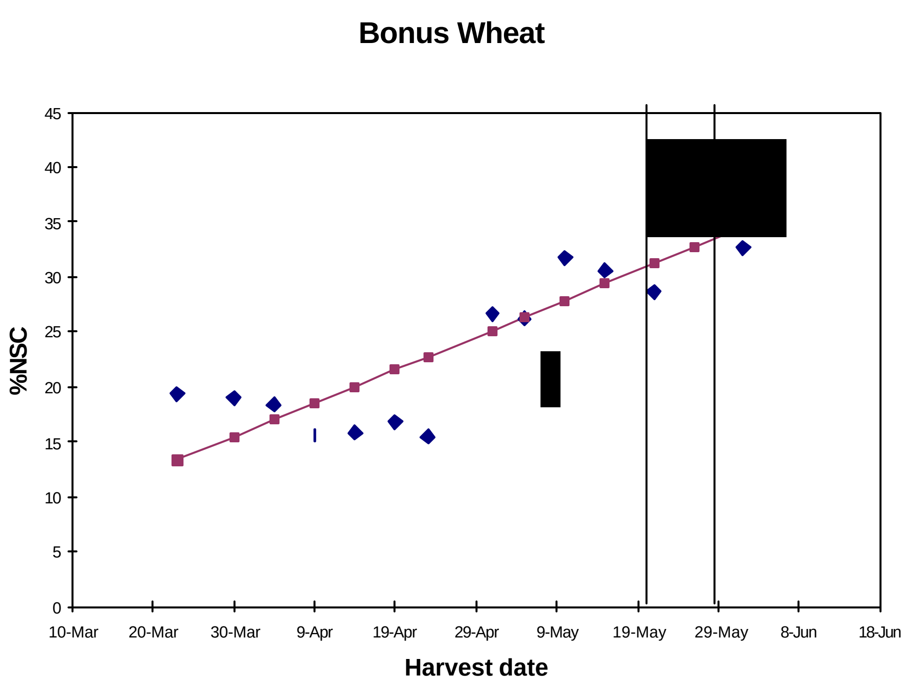
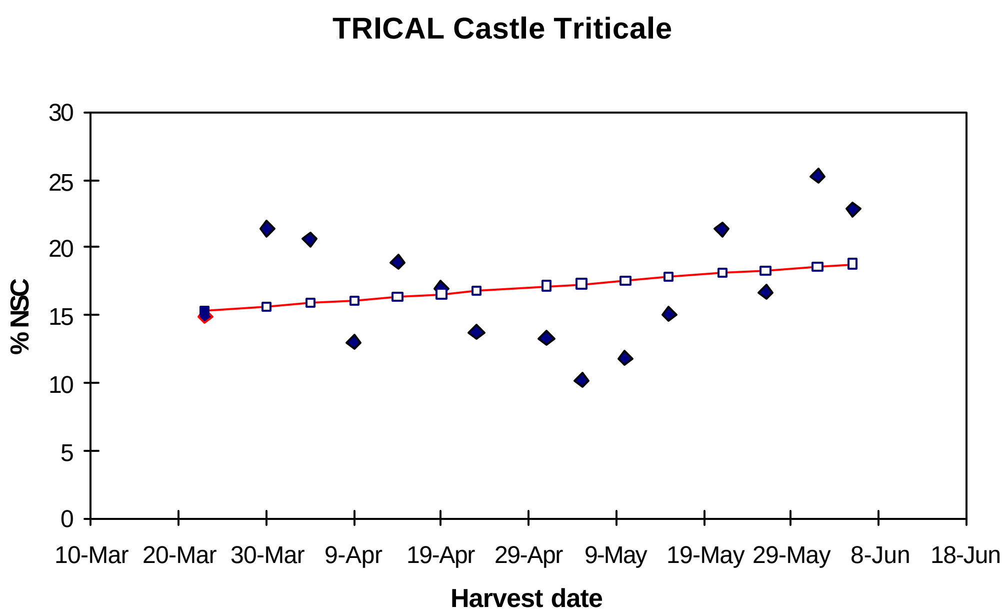


Figure 4



Changes in in-vitro total digestibility – Figures 5 and 6 show what happens to IVTD with advancing maturity. Percent IVTD is highest when the plants are immature. It tends to drop off sharply as the plants begin heading out and then levels out or may even increase slightly as the grain begins to fill with starch. The drop in IVTD corresponds to decreasing NSC, and increasing lignification of fiber in the stems and leaves. The leveling off occurs as highly digestible starch dilutes out the effects of less digestible fiber.

Figure 5.

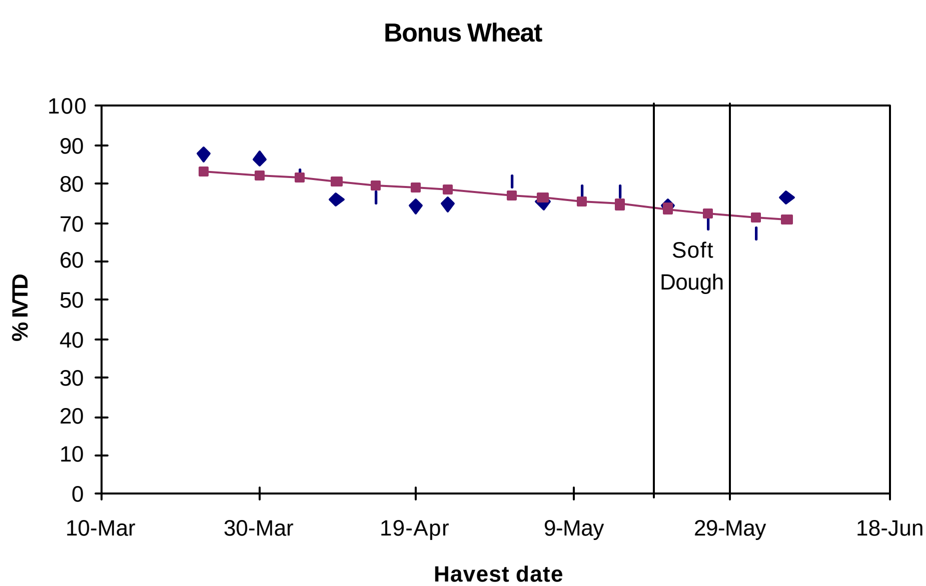
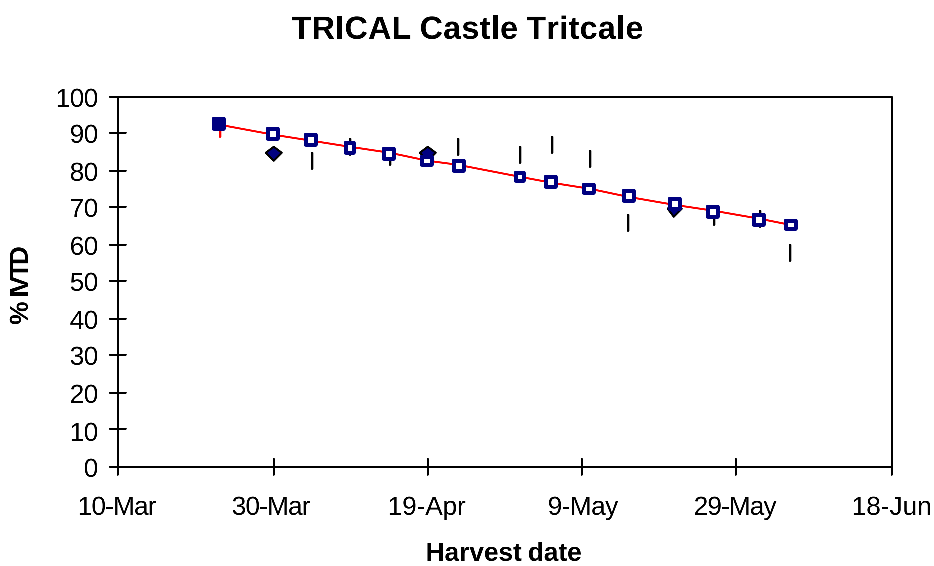


Figure 6



Changes in digestible Neutral Detergent Fiber - NDF is a measure of cellulose, hemicellulose and lignin which are structural, fiberous components of plants. Cellulose and hemicellulose are digestible components of the fiber that provide energy to cattle. Lignin is not digestible and its presence reduces the digestibility of other plant constituents. *In vitro* tests similar to the IVTD test can be conducted to estimate digestible NDF of forages. Figures 7 and 8 show the relationship of digestible NDF to harvest stage. Digestible NDF clearly decreases with advancing forage maturity. The drop is more pronounced than the decrease seen for IVTD with advancing maturity. Lower digestible NDF with advancing maturity reflects lignification of the forage fiber. As digestibility of the NDF decreases, so does the energy value of the forage.

Figure 7.

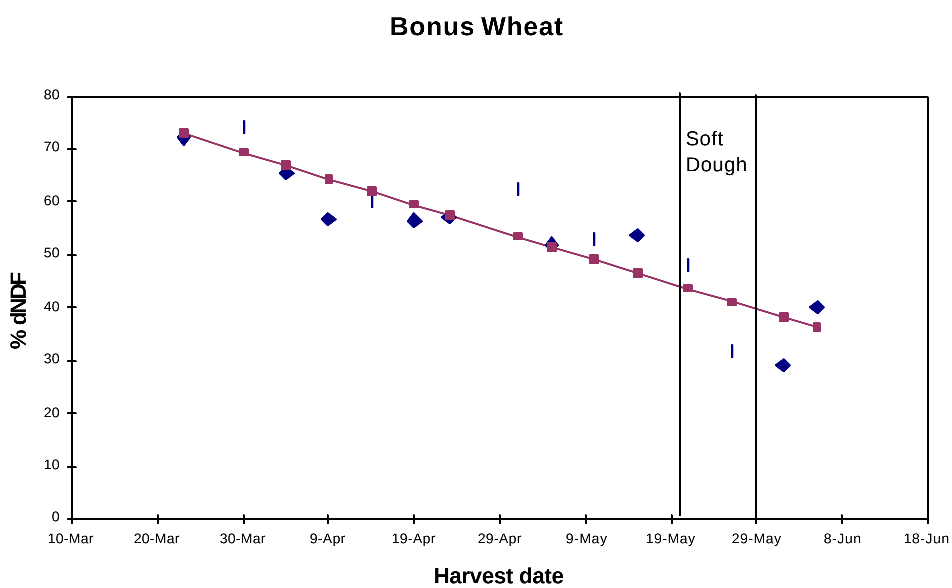
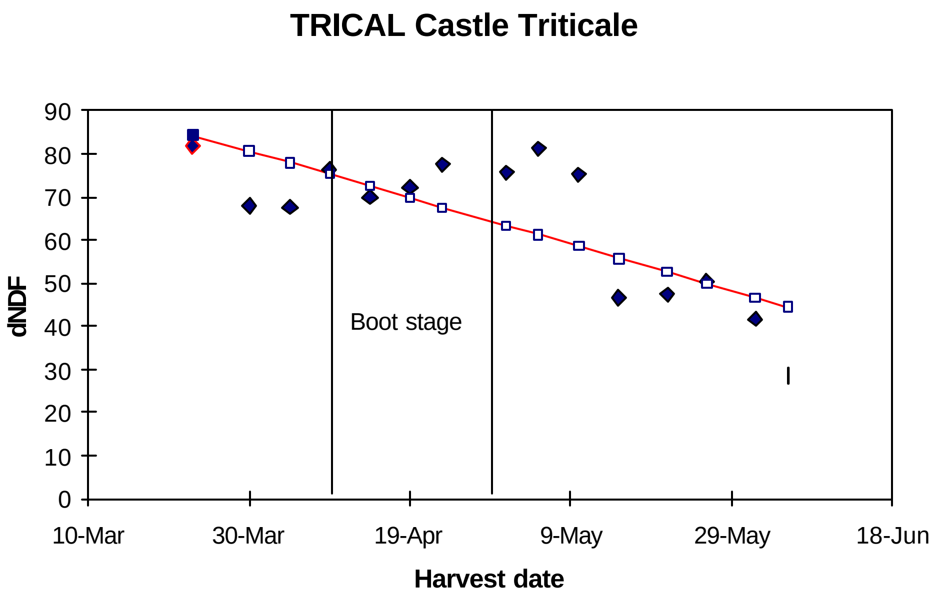


Figure 8



Clearly, early cut immature winter cereals have superior nutritional value for animals. So why does any one even consider soft dough stage forage? The answer is tonnage.

Maturity at harvest effects on yield - Dry matter yields of winter cereal forages are lowest at boot or early harvest stages compared to soft dough stage harvest. Boot stage yields can average anywhere from 8 to 15 tons per acre, while soft dough stage yields generally average 16 to 25 tons per acre. In harvest stage trials, boot stage yields were 30 to 60% lower than soft dough; as a general rule one can estimate about half the yield at boot than what would be expected at soft dough. This is highly dependent on cultivar. There is a tremendous variation in yield at each growth stage and also in when that growth stage occurs, depending on what is planted. Later maturing cultivars tend to have higher boot stage yields because they have more time to accumulate dry matter.

The tremendous yield difference is the main reason that there has been reluctance to harvest at boot stage despite its superior feeding value. It is the age-old dilemma of quality vs. quantity. Unless growers are compensated for the higher quality, there is little incentive to take such a big hit on yield. Another reason why boot stage forage has not been widely accepted may be that its feeding value has been underestimated by standard forage quality tests that predict energy from fiber. Some other challenges to boot stage harvest or use of boot stage forage that should be mentioned include the following:

- difficulty in field wilting because of unfavorable weather
- potential high nitrate content
- potential high potassium content
- poor ensiling characteristics

Cool temperatures and rain are conditions that can occur in early spring. Unlike soft dough stage forage which can be direct chopped for silage, boot stage forage is very wet – 80 to 85% moisture- so it must be field wilted prior to ensiling. The weather does not always cooperate. Selecting a late maturing forage may help. Boot stage forage swathed in mid-April has better weather conditions for field wilting compared to cultivars that are swathed at boot stage the third week of March.

Winter cereal crops that are harvested at boot stage have the potential to contain high levels of nitrates, especially if they are from fields that have received heavy applications of manure or high levels of commercial fertilizer (12). Harvest during cool, cloudy conditions can also contribute to the problem. High nitrates in feed can be toxic to animals. Ensiling is the best method to reduce plant nitrate after harvest. Even though much of the nitrate may be degraded in the silage pit, routine analysis of boot stage forage for nitrate levels would be a wise investment for dairy producers.

Forage from fields that have received heavy manure applications may contain relatively high levels of potassium. High potassium in dairy forage is a concern for managing milk fever, a metabolic disorder in dairy cows that occurs around calving time. Prevention of milk fever involves balancing cations and anions in a dairy ration (13). The dietary cation-anion difference (DCAD) is a tool that nutritionists use in formulating rations to manage milk fever. Potassium is a cation. High levels of potassium in forage contribute to a high DCAD, which can cause more milk fever when it is fed to dry cows that are close to calving. Dairy producers can adjust the DCAD level by adding magnesium salts to the dry cow ration, but identifying forages that are low in potassium may be more economical and effective. High potassium levels are not just unique to boot stage forage. Soft dough forage can have high levels as well.

Fermentation of boot stage forage may be poor if moisture levels are too high. Ideally the forage should field wilt from about 85% moisture to around 70% moisture before chopping, but sometimes the weather does not cooperate. If a grower is lucky enough to have an especially heavy crop at this stage, then field wilting may be even more difficult because of the large mass of forage in each swath. Poorly fermented forage is more apt to spoil and cause feed intake problems. Field drying of early cut winter forages is an area that needs further study.

SUMMARY

Small grain forages are extremely versatile, economical sources of feed that have long been over shadowed by alfalfa and corn silage. Standard laboratory tests and prediction equations for defining nutritional value are not reliable for small grain forages. Inaccurate feeding value information may be part of the reason why these forages have not been utilized to their full potential. The recent introduction of *in vitro* procedures for estimating energy value will provide more reliable information that can help nutritionists and producers take full advantage of the nutritional attributes of small grain forages. Dairy animals have diverse nutritional needs. For example, growing heifers, dry cows and lactating cows all receive different rations that are formulated to fit the particular requirements for each group. Small grain forages are best utilized by "matching the feed to the need." Highly digestible boot stage forage is a good fit for the nutritional needs of high producing dairy cows. Lower energy soft dough stage forage is a better match for the nutritional needs of dry cows and growing heifers. There is tremendous diversity in plant types that are suited for different end uses. Depending on which cultivar or variety is chosen, and how it is managed, small grain forages can meet a dairy's full range of forage needs.

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