EQUINE GRAZING PREFENCES AND FORAGE QUALITY OF COOL-SEASON FORAGE GRASSES

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ELIZABETH ALLEN

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Chapter 1

Review of Literature

Forages and Horses

It is generally assumed that, on average, horses need to consume about 2% of their body weight (BW) in feed on a dry matter (DM) basis per day. Horses are herbivores, meaning they evolved to eat vegetative grasses, legumes, herbs and shrubs. A majority of horses in Minnesota spend a significant amount of time being housed on pasture where free grazing is available (Martinson et al., 2006). Depending on the amount of time they spend grazing per day; many horses are able to meet most, if not all, of their daily energy requirements on pasture.

Grass pastures consist of two main types of forage grasses, cool-season and warm-season. Cool- season grasses survive well in temperate climates, whereas warm season grasses thrive in subtropical or tropical climates. A forage plant consists of the leaf, sheath, flower, and seed head. All portions of the plant contain both chemical and nutrimental compositions that vary depending on the stage of growth, time of year, climate, soil type and fertility (NRC, 2007). Forages are high in dietary fiber which is composed mostly of structural carbohydrates (SC) and lignin found in the plant cell wall (Longland et al., 1995; MAFF, 1992). Other contents include nonstructural carbohydrates (NSC) that include simple sugars such as glucose, fructose, sucrose, starch, and fructan (Beever et al., 2000).

Forage, in the form of hay or pasture, typically represent a majority of the diet for adult horses. Forages should never be less than 50% of the total diet, and adult idle horses can receive their entire energy requirement from forages alone (NRC, 2007). Cool-season grasses usually contain 350 to 650 g of cell wall carbohydrates/kg DM which is comprised of 60% cellulose, 30 to50% hemicelluloses, and 2 to 4% pectins (Longland et al., 1995). These carbohydrates represent the non-starch polysaccharide portion of the plant cell wall. Pectins are readily degradable by the microflora of the hindgut, while celluloses and hemicelluloses are more resistant to microflora breakdown (Graham et al., 1986; Moore-Colyer and Longland, 2000). As the plant matures these fractions become more lignified and indigestible thus decreasing nutritional value and digestibility (Dulphy et al., 1997). Several environmental factors influence cell wall content in forages, including changes in temperature or season. For example, plants grown at warmer temperatures tend to increase cell wall content (Deinum et al., 1968) and lignification (Wilson et al., 1991) which reduces their feeding value.

The cell contents of forages include simple sugars, fructan, and starch which make up the NSC portion, and most of the protein, minerals, and lipids of the plant (NRC, 2007). As forage matures, NSC decreases which lowers digestibility. The cell contents of legumes tend to decline more quickly than in grasses (Beever et al, 2000).

Starch is the major storage carbohydrate of legume species and warm-season grasses whereas fructan is the major carbohydrate storage of cool-season grasses (Chatterton et al., 1989; Ojima and Isawa, 1968; Smith, 1968; Bender and Smith, 1973). When there is an excess of photosynthetic activity during rapid growth and metabolism of the plant, carbohydrates are converted to fructan and distributed from the leaf to the stem (NRC, 2007). Fructan production is not self-limiting, and high levels tend to accumulate in cool-season grasses during the spring months when the grasses are rapidly growing (Chatterton et al., 1989). High levels of fructan result in increased intake and digestibility, which has been known to contribute to metabolic disorders such as laminitis, colic, obesity, and the development of insulin resistance (Hoffman et al. 2003). Fructan and water-soluble carbohydrate levels vary between species of pasture grass (Longland et al., 2006; Vervuert et al., 2005). Levels of starch, fructan, cell wall content, and other nutrients are similar for cool-season grasses but do vary somewhat depending on the species (NRC, 2007).

There are a number of different species of cool-season grasses as well as different varieties within each specie. More common pasture grasses include Kentucky bluegrass (*Poa pratensis* L.), tall fescue (*Schedonorus phoenix* Scop.), meadow fescue (*Schedonorus pratensis* Huds.), perennial ryegrass (*Lolium perenne* L.), reed canarygrass (*Phalaris arundinacea* L.), orchardgrass (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leyss.), meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.), timothy (*Phleum pretense* L.), and different types of legumes (NRC, 2007). Legumes such as alfalfa (*Medicago sativa* L.) and white clover (*Trifolium repens* L.) are good sources of protein and calcium, and enhance the nitrogen status of the soil. They are, however, susceptible to aggressive defoliation and hoof traffic (NRC, 2007). This review will focus mainly on cool-season grasses which will be discussed later in greater detail.

Many horses in the Midwest and northeast are housed and maintained on pastures where cool-season grasses are prevalent. Most pasture grasses are able to support horses at maintenance energy requirements and some have even been known to support horses with higher energy needs such as mares during gestation and lactation (Gallagher and McMeniman, 1988). Pastures have even been reported to support growing horses up to 3 years of age (Bigot et al., 1987; Staun et al., 1989). As long as pastures are not over stocked (average stocking rates of 2 acres per horse), animals spend enough time grazing, and recommended pasture management is implemented, pasture grasses are able to maintain horses at most energy levels. If a pasture is well managed, grass yields average around 2 tons DM/hectare (5 tons/acre per year) which theoretically means it should provide sufficient forage DM for a 500-kg horse that needs 10 kg DM/day (NRC, 2007). If pastures are rested, rotated, and managed, expected yield can be increased. Co-grazing is also effective as cattle and sheep have different grazing habits than horses. Cattle and sheep tend to be less selective in their choices and are less likely to overgraze than horses (Archer, 1973b). Additionally, ruminants will eat the "roughs" (mature areas) that horses leave behind as long as it has not become too neglected (Archer, 1978b). This allows for uniform pasture consumption and decrease the incidence of overgrazing which can lead to areas of weed invasions (Archer, 1978b). Well managed pastures can be an effective form of housing horses for horse owners.

It is important to note that horses are not production animals, and do not produce a quantified output such as milk or meat, which can be easily measured and calculated. In order to assess whether forage is having an impact on horse health, methods such as change in body weight can be analyzed (Ince et al., 2005), fecal output and known organic matter or dry matter digestibilities can be measured (Meschonia et al, 1998; Grace et al., 2002), or other various techniques can be used to determine absorbed nutrient levels (NRC, 2007). Additionally, to measure grazing preference, observations can be taken to account for time spent grazing a particular species and intake can be accounted for by measuring yield before and after a grazing event. These factors are important when assessing whether pastures are a viable option for a particular horse.

Cool-Season Forage Grasses

Cool-season grasses are the foundation of pastures in the Midwest with many varieties popular in other regions of the country (NRC, 2007). Though research is limited on newly developed varieties of cool-season grasses, plenty of background information on many of the foundations of these species exists.

Moser and Hoveland (1996) determined that cool-season grasses grow well between 20 and 25° (C) and can grow at temperatures as low as 5°C at as high as 35° C. However, they are dormant during the winter months at lower altitudes. Moser and Hoveland also determined that a majority of cool-seaon grasses are produced in the spring when temperatures are near optimum and moisture supply is adequate while little production is noted during the drier, hotter summer months. Cool-season grasses use what is known as the C_3 photosynthetic pathway for carbon (C) fixation whereas warm-season grasses us the C_4 pathway (Waller & Lewis, 1979). C_3 photosynthetic rate is less than half that of C_4 grasses under light saturation and they are also less water efficient, using up to three times as much water per unit of DM production. This only inhibits productivity during high temperatures and dry conditions (Moser and Hoveland, 1996).

For reproduction to occur, cool-season grasses require a short-day and vernalization or a long-day followed by a short-day requirement (Moser and Hoveland, 1996). This means the plant should be exposed to cool temperatures in order to bloom, and though this is not always required, it is optimal for flowering characteristics. Due to these requirements, only one major set of seedheads is produced each year, usually in late spring, and then remain vegetative for the rest of the season.

Mosler and Hoveland determined that cool-season grasses are high in digestible energy (DE) as well as protein, especially during the vegetative stage of maturity. They average 700 g kg^{-1} (g/kg) in digestibility for the overall season (Ulyatt, 1981). This high level of digestibility is due to the leaf tissues that break down rapidly during digestion. Crude protein (CP) content is higher in grasses that are in the immature stage (Mosler and

Hoveland, 1996) and concentrations average 129 g/kg DM (Minson, 1990). Forage quality can be defined as the relative performance of animals when herbage is fed *ad libitum* to livestock (Buxton et al., 1996). This includes the impact of nutrient concentration, intake potential, digestibility, and partitioning of metabolized products within the animal. Even though cool-season grasses on average are high in DE they may not always meet the nutrient and energy requirements of moderate-to-high producing or exercising animals.

An important factor when determining forage quality is cell-wall concentrations which is can be measured using the detergent-fiber system (Goering and Van Soest, 1970; Van Soest and Robertson, 1980). Cell-wall concentration is estimated by neutral detergent fiber (NDF), hemicellulose as NDF minus acid detergent fiber (ADF), and cellulose as ADF minus lignin-plus-ash. Acid detergent fiber contains cellulose and lignin while NDF if also comprised of those elements plus hemicellulose. Stems contain a greater proportion of cell wall compared to leaves of the plant and are usually lower in digestibility. Stem digestibility declines more quickly than that of the leaves with increased plant maturity (Collins and Moore, 1995). While lignin is not digested by the horse, ADF and NDF components are partially digestible with hemicelluloses being slightly more degradable than cellulose (Fonnesbeck, 1969).

All cool-season grasses have their own unique traits as well as differing nutrient levels that make them desirable for a wide variety of agricultural operations or, more specifically, livestock pastures. Tall fescue is prevalent in the US due to its ability to adapt to a wide range of soil conditions, tolerance to continuous grazing, high yields, persistence and ground cover, long grazing season, compatibility with multiple management practices, and resistance to pests (Hansen, 1979). In a study by De Sousa et al. (1982), out of 71 tall fescue genotypes *in vitro* dry matter digestibility (IVDMD) averaged 570 g/kg when harvested in May at the late boot stage, 653 g/kg in October, and 560 g/kg in August during the dormant season. In the same study NDF and ADF averaged 678 and 397 g/kg respectively in tall fescue when harvested in the late boot stage in the spring and 405 and 215 g/kg respectively for October harvests.

Orchardgrass varieties are well adapted to humid, cool, temperate regions with greater than 500 mm of annual precipitation and average to good soils (Hodgson, 1977). It is one of the most productive cool-season species as a bunchgrass and has exceptional early spring growth and good summer and fall productivity (Mitchell, 1967; Washko et al., 1967). Orchardgrass is highly responsive to fertilization (N) which substantially increases DM yield (Van Santen and Sleper, 1996). Collins and Casler, (1990a, b) found that IVDMD levels of orchardgrass often declined below 600 g/kg on average 2 days before other species such as smooth bromegrass or tall fescue. Forage quality of orchardgrass declines steadily from the early vegetative stage to reproductive maturity (Kühbauch and Voigtländer, 1979). Orchardgrass can be classified as early to intermediate in reproductive maturity, intermediate in protein content, high in fiber, and intermediate to high in lignin (Dent and Aldrich, 1963; Kunelius, 1990; Phillips et al., 1955). Orchardgrass is known to be productive in the spring and during in other production periods (Mitchell, 1967). Average daily dry matter accumulation (ADMA) was more uniform than other species in Canada, ranging from 53 kg ha^{-1} d^{-1} to 94 kg ha^{-1} d^{-1} (Kunelius, 1990). Although, in stockpiling conditions ADMA is known to decline more sharply in late fall with no net accumulation after mid-November in Kentucky (Dougherty, 1983).

Smooth bromegrass is similar to orchardgrass in its adaptations and concentration of growth distribution due to its cold tolerance, winter hardiness, and drought tolerance (Vogel et al., 1996). Though less drought tolerant, this grass is an excellent seed producer and continually produces reliable seed yields annually. It also has good seedling vigor, establishes well in early spring or fall, and is very persistent and productive. Meadow bromegrass also grows in the same areas as smooth bromegrass and is not as winter hardy or drought tolerant but does well in cool, moist regions (Knowles et al., 1993). As a determinate species, bromegrass' forage quality declines as plants mature and herbage IVDMD and CP concentrations correlate with calendar day and accumulated growing degree days (Vogel et al., 1996).

Reed canarygrass is known to be best suited for pasture as it produces a heavy thick sod which survives well under grazing and is well adapted to low-lying wet areas but is still fairly drought tolerant (Carlson et al., 1996; Pammel et al., 1901). It is one of the highest yielding cool-season grasses and is persistent under a wide range of harvest management practices and N applications (Decker et al., 1967; Marten et al., 1979; Marten and Hoven, 1980). Other phalaris species' vegetative herbage is about equal in nutrient value to that of other temperate grasses (Freer and Jones, 1984). During elongation of the spring digestibility and protein concentrations decrease to low levels though the leaf laminas stay above 550 g/kg digestibility (Clements et al., 1970).

Ryegrass is the primary grass used for pasture in animal production in the world (Jung et al., 1996). Perennial ryegrass is adapted to a wide variety of climates including those with harsh climates, severe winters, or mild maritime climates. It demonstrates high herbage yield, has a long growing season, is tolerant to a range of environmental conditions and grazing practices, has excellent persistence, and high palatability. Ryegrass contains readily available energy for livestock containing one of the highest NSC ranges, especially in the spring (Jung et al., 1974 and 1976). Total NSC levels can range from 160 g/kg to 350 g/kg in the fall (Jung et al., 1996). Waite et al., (1964) found CP levels of perennial ryegrass to range from 96 to 185 g/kg from seed setting to the young-leafy stage, respectively, and Jung et al. (1982) found mean IVDMD concentrations of some varieties of 774 g/kg. Ryegrasses, however, are not as tolerant of high temperatures (Mitchell, 1956).

Timothy grows well in cool, moist climates and can survive harsh overwintering conditions and thus thrives in regions with shorter growing seasons and cold winters, it does not survive well under hot, dry conditions (Berg et al., 1996). It does not withstand frequent harvesting and cutting during stem elongation (Grönneröd, 1986). However, timothy has been known to persist well when harvests per season were increased from three to eight (Jung et al., 1974). DM Digestibility of timothy during the immature growth stages is high at greater than 800 g/kg, but can decline depending on variety and environment (Mason and Lachance, 1983). Total nitrogen, CP, and digestibility all decrease with age and maturation (Collins and Casler, 1990b). Timothy is highly palatable to livestock on pasture, although is not as persistent as perennial ryegrass (Kunelius and Narasimhalu, 1993).

A sod forming grass, Kentucky bluegrass, withstands high amounts of animal traffic (Wedin and Huff, 1996). Though initially slow to establish, bluegrass grows well in a wide range of climate conditions, but is limited by temperatures higher than 23˚C (Hartley, 1961). Another advantage of bluegrass, other than its turf forming capabilities, is its high level of persistence under continuous and heavy grazing, even by horses and sheep (Duell, 1985). Though typically high in forage quality, bluegrass is low yielding due to its rapid maturation and lack of height compared to other cool-season grasses (Wedin and Huff, 1996). However, Hockensmith (1991) found that of six grasses studied, Kentucky bluegrass was the slowest to decline in quality ratings including IVDMD, NDF, and CP.

Creeping foxtail (*Alopecurus arundinaceas* Pior.), another cool-season grass common to temperate climates, is adapted to a wide range of soils, pastures, and climates being fairly winterhardy (Boe and Delaney, 1996). Foxtail varieties are typically used in conditions where there are a limited number of other adapted species. It grows and survives well in pastures in early spring, and is also commonly used to prevent soil erosion (Stroh et al., 1978) with ideal traits for waste water disposal in overland flow municipal waste water treatments (Borrelli et al., 1984). Although creeping foxtail has excellent cold tolerance and is moderately tolerant to drought periods, growth rate in low moisture conditions is limited (Schoth, 1945). Creeping foxtail should be harvested and grazed before anthesis or advanced maturity to obtain higher productivity and quality. Quality levels such as CP, dry matter digestibility (DMD), and yields are similar to that of timothy due to early utilization (Waldie et al., 1983).

Previous Research on Cool-Season Grasses

Information on cool-season grasses is wide and varied. Yield, quality, and persistence differ depending on species, weather, location, and agronomic management.

Jung et al. (1974) found that persistence of Kentucky bluegrass, tall fescue, orchardgrass, and timothy improved as harvesting or clipping frequency over a season was increased from three to eight cuts per year, however, reed canarygrass and smooth bromegrass tolerated less frequent harvests. In the same study, orchardgrass was found to be the most productive species. Jung et al. (1974) also found that in the second year of harvest, yields, along with a higher rate of nitrogen, were highest with three clippings in orchardgrass, reed canarygrass, and smooth bromegrass at about 14.5 MT/ha, 6 MT/ha, and 15 MT/ha respectively. Tall fescue and timothy yields were highest with five clippings at about 12 MT/ha and 7 MT/ha respectively, and Kentucky bluegrass yields were highest with eight clippings at 6 MT/ha. At a low rate of fertilizer, all species, except Kentucky bluegrass and timothy, produced highest yields with three clippings (6 to 14 MT/ha). Timothy yields were highest with five clippings with 6 MT/ha, and clipping frequency had little effect on bluegrass yields averaging around 5 MN/ha for all clippings (Jung et al., 1974).

In a similar study conducted by Marten and Hovin (1980) grasses were harvested at two, three, and four cuttings for three years. Grasses established included smooth bromegrass, tall fescue, orchardgrass, and reed canarygrass. Persistence was estimated by two trained estimators and expressed as the mean of the two estimates in May of each year. A “perfect stand” was defined as one in which 100% of the plants were of the designated species and in which 100% ground cover existed. With four harvests, smooth bromegrass persistence was the lowest at 40% ground cover, although recovered closer to 76% cover when switched to three cuttings, tall fescue and orchardgrass persistence was the lowest at 50% and 74% respectively with the two-cuttings, and reed canarygrass had the highest persistence remaining at 94% and above regardless of cutting schedules. Crude protein concentration in reed canarygrass declined most rapidly, while orchardgrass and tall fescue declined the slowest. Crude protein dry weight (DW) concentrations for reed canarygrass at two cuttings were 15.8%, 12.4%, and 11.5%, at three cuttings were 20.2%, 15.8%, and 14.8%, and at four cuttings were 23.8%, 19.1%, and 20.3% for the first, second, and third years of establishment respectively. Crude protein dry weight (DW) concentrations for orchardgrass at two cuttings were 15%, 12%, 11.2%, at three cuttings were 17.7%, 13.6%, and 13.2%, and at four cuttings were 19.6%, 15.1%, and 14.9% for the first, second, and third years of establishment respectively. Crude protein dry weight (DW) concentrations for tall fescue at two cuttings were 14.6%, 12.8%, and 11.2%, at three cuttings were 16.8%, 12.8%, and 11.8%, and at four cuttings were 18%, 14.1%, and 14.3% for the first, second, and third years of establishment respectively. The grasses did not differ greatly in the rate of cell wall concentration increase ranging from 47% to 58% for every year and all cuttings.

Cherney et al. (1986) established tall fescue, reed canarygrass, and orchardgrass under a two-harvest management system, with a combination of three fertilization rates and five first-harvest dates at two-week intervals. Nitrogen fertilization was applied as ammonium nitrate annually at rates of 0, 168 and 336 kg ha^{-1} in early spring at the onset of new growth. The two-cut management system during 1982 and 1983 included a fall harvest during the last week of October, along with five first-harvest dates at two-week intervals, beginning in late May. In late May 1984 a final residual harvest was taken after a spring application of 112 kg N ha^{-1} on all plots. Initial first-harvest dates for all species over the three-year period were between May 19th and May 26th. Reed canarygrass persisted and yielded well under two harvests, regardless of the time of the first harvest averaging 10.6 Mg ha^{-1} over two years with tiller densities averaging 636 m^{-2} in 1982, 408 m^{-2} in 1983, and 521 m^{-2} in 1984. Tall fescue tiller density declined with high N fertilization in 1982 with 2202 m^{-2} at 0 N fertilization and 1752 m^{-2} at 336 kg ha^{-1} N fertilization but were not affected by a later first-harvest date. Orchardgrass stands did not persist well and were eliminated by the two-harvest management system dropping from 1222 m^{-2} to 942 m^{-2} in 1982 and 1220 m^{-2} to 521 m^{-2} in 1983 with a delayed first-harvest date. Neutral detergent fiber concentrations were above 550 g kg−1 for all grasses and permanganate lignin concentrations were generally above 40 g kg−1 (Cherney et al. 1986).

Marten et al. (1987) compared alfalfa to smooth bromegrass and quackgrass (*Elymus repens* L.) and common weed species in a study evaluating forage quality and palatability in sheep. Palatability was estimated by observers who were previously trained to score relative palatability of forages via visual observation of the plots before and after grazing. Grasses were scored on a scale of 10% to 100% where 100% indicated complete rejection and 10% indicated that only short stubble remained. The grasses were found to have consistently more NDF than weeds averaging 551 g kg^{-1} NDF in 1981 and 456 g kg-1 NDF in 1982 with weeds averaging 471 g kg^{-1} in 1982 and 346 g kg^{-1} in 1982. Weeds generally had lower palatability than alfalfa or smooth bromegrass averaging close to

100% or less rejection whereas grasses were closer to 60% rejection while palatability of a quackgrass biotype, with an average of 40% rejection, was equal or superior to smooth bromegrass, which averaged 52%, and were equal to alfalfa, which averaged 30%, in two of the three trials. However, common quackgrass consistently had lower palatability than smooth bromegrass or alfalfa (Marten et al. 1987).

Maturity is also an essential component to pasture management and several studies have compared the effect of grass maturity on forage quality. Collins and Casler (1990a) established stands of smooth bromegrass, orchardgrass, timothy, tall fescue, and reed canarygrass in a two year field study. Grasses were sampled seven times during the growing season and fertilized annually. Timothy was the highest *in vitro* dry matter disappearance (IVDMD) at 661 g kg−1 with orchardgrass being the lowest at 615 g kg−1 with reed canarygrass and tall fescue in between. Orchardgrass maintained the highest average neutral detergent fiber (NDF) concentration with 624 g kg^{-1} whereas tall fescue was the lowest, at 576 g kg^{-1} on average. Reed canarygrass NDF was found to increase more rapidly with maturation than smooth bromegrass and timothy averaging 607, 614, and 601g kg^{-1} respectively. Timothy and smooth bromegrass declined least rapidly in quality and timothy had the highest average IVDMD, but tall fescue had a lower average NDF concentration possibly demonstrating that differences in cell-wall digestibility between species may also exist (Collins and Casler, 1990a). These findings indicate that reed canary grass and, to a certain extent, tall fescue change more rapidly in quality with maturation than other species and thus would need to be utilized at an earlier stage of maturity in order to have similar levels of forage quality.

Hockensmith (1991) analyzed the changes of NDF and CP in smooth bromegrass, tall fescue, Kentucky bluegrass, orchardgrass, timothy, and reed canarygrass with stages of maturity. Grasses were harvested in the spring at weekly intervals at two locations and assessed for maturity as defined by Simon and Park (1983). Neutral detergent fiber concentrations increased while CP declined with maturation. At both locations, orchardgrass had an average NDF of 697 g kg^{-1} with CP concentration averaging 108.5 g kg^{-1}, Kentucky bluegrass averaged 655 g kg^{-1} of NDF and 114.5 g kg^{-1} of CP, and reed canarygrass had a season average of 652 g kg^{-1} NDF and 95.5 g kg^{-1} CP. The results showed that overall forage quality differs between species in rate of decline with maturation (Hockensmith, 1991).

In a review on grazing tolerance of temperate perennial grasses in Australia, Kempa and Culvenorb (1994) defined a grass's tolerance to grazing as its influence on the sward components of a grass. For example, sward growth rate is influenced by plants per hectare, by tillers per plant, leaves per tiller, and leaf growth rates. They also contemplated whether grazing tolerance was minimizing death of leaves, tillers, buds, and/ or plants after grazing and/or maximizing growth of leaves and/or tiller buds after grazing. They conclude that the best way to enhance grazing is to maintain a high density of plants and tillers that have low growing points, so they can regenerate quickly after grazing, or adverse seasonal conditions. They also concluded that selecting plants that are drought tolerant and grow faster during rainfall is possibly more cost-effective for plant improvement (Kempa and Culvenorb, 1994).

A more recent study by Brink et al. (2007) evaluated canopy density or the vertical distribution of DM and NDF within temperate perennial grass swards which can influence pasture intake by livestock. Plots of Kentucky bluegrass, perennial ryegrass, orchardgrass, timothy, tall fescue, soft-leaf tall fescue, meadow fescue, smooth bromegrass, reed canarygrass, and common quackgrass were broadcast seeded on a prepared seedbed in April 2003. Data was collected in 2004 and 2005 and when grasses reached a height of 25 cm in spring, summer, and fall, canopy layers were harvested from 20 to 25, 15 to 20, and 10 to 15 cm. With higher precipitation levels in the spring, quackgrass had greater upper canopy density than any other grass. Grasses typically grazed at shorter heights such as bluegrass and perennial ryegrass had greater density in the lower canopy. Tall fescue, reed canarygrass, and meadow fescue had lower density in the upper canopy than timothy and quackgrass in the spring while the reverse was true in the summer. Moreover, NDF of grasses generally increased from the upper to lower canopy layer with higher NDF concentrations in the lower canopy and perennial ryegrass and meadow fescue often had the lowest NDF overall. They concluded that pasture intake may benefit from a diverse species composition because animals can graze a mixture having optimum density and NDF throughout the canopy (Brink et al., 2007).

Additionally, grass height does not seem to affect forage quality in the summer months after the spring growth season (Cosgrove and Behling, 2010). Beginning in early May, plants were measured for height and quality every three to four days until they were fully headed, then harvested. The process was repeated to measure the relationship between height and quality during the vegetative growth stage. Based on the results, grazing should be initiated starting at 10 inches for smooth bromegrass, orchardgrass and reed canarygrass and should cease at four inches tall in the spring when quality levels are higher. Grazing of Kentucky bluegrass and perennial ryegrass should begin at six inches tall and end at two inches (Cosgrove and Behling, 2010). In the mid-summer months when grasses tend to become more dormant, he proposes they remain in the vegetative state and forage quality does not decrease with height.

In a 2010 study (Pelletier et al., 2010), variations in total nonstructural carbohydrate (TNC) concentrations of grass and legume forages at different times of the day and the relationship of TNC to other nutrients in the plant was investigated. Several species of grasses and legumes were cut at 0900 (AM) and 1530 (PM) hours in spring and summer over two harvest years. Total nonstructural carbohydrate concentrations were determined by summation of sucrose, glucose, fructose, starch and pinitol in legumes, and fructans in grasses. The highest concentration of TNC was observed in Red clover (*Trifolium pratense* L.) and tall fescue with 94.2 g kg^{-1} of dry matter (DM) across AM and PM harvests. Reed canarygrass was the lowest in TNC with 65.5 g kg^{-1} DM. An increase in TNC concentrations at the PM cutting was seen in all species, although the amount of increase varied across species and ranged from 13% in smooth bromegrass (67 to 74 g kg^{-1} DM) to 68% in reed canarygrass (50 to 81 g kg^{-1} DM). Decreases in nitrogen, ADF, and NDF as a result of increases in TNC at the PM-cutting were small but significant. It was concluded that both species selection and afternoon cuttings can be used to increase TNC concentrations in forages (Pelletier et al., 2010).

Oates et al. (2011) conducted an experiment on pastures dominated by Kentucky bluegrass, orchardgrass, meadow fescue, perennial ryegrass, and white clover to compare forage production, forage quality, and root production under management-intensive rotational grazing, continuous grazing, haymaking, and land with no agronomic management. Some plots were rotationally grazed by cow-calf pairs while others were designated for haymaking and harvested twice per growing season. Potential utilizable forage (PUF) and relative forage quality (RFQ) were significantly greater under the rotational grazing system when compared to the other treatments with PUF totaling above 1000 g dry biomass m^{-2} for both years while the other grazing systems remained under about 950 g m^{-2} DM. Relative forage quality for the rotational grazing system averaged around 145 in 2006 and 155 in 2007 whereas the other systems were typically around or lower than 137. An estimate of 137 RFQ is the level at which forage is thought of as medium quality and were growing cattle would gain 0.6 kg d^{-1} and lactating cows would produce 10 kg milk d^{-1}. The results point to managed grazing as a viable alternative to continuous grazing and haymaking in terms of both forage production and quality (Oates et al., 2011).

Previous Research on Equine Pasture Management

While taking into account the varying species of grasses and how to manage them for an equine pasture, it is important to understand that horses are selective grazers and tend to spend more time consuming the species they prefer before moving on to a less palatable species (Archer, 1973a). They are able to use their lips and tongues to differentiate between forages they are grazing, and can even discard plants or grasses already taken into the mouth if they find it not as palatable (Archer, 1980). Although taste preferences between individual horses vary, (Randall et al., 1978), less is known about individual preference between forages. If horses are allowed free choice grazing, grass palatability is the main factor that effects forage selection (Archer, 1980). However, there is little current research regarding equine grazing preference. Archer (1971) began a preliminary study on palatability of grasses, legumes, and herbs using 29 pure botanical species with two seed mixtures. Two crossbred ponies and one thoroughbred were grazed on 30 randomized strips with one species in each strip. Planting began in 1968 in Suffolk, England and the ground was tilled and herbicides were used to control weeds and fertilizer was applied before sowing. The horses were grazed starting in April of 1969 until September and then again April through October of 1970. The pasture was rested October through March between grazing periods and periodically during the grazing year.

In addition, timed recordings and observations were taken each time the horses were grazing a strip. Purity of the plots was measured and droppings were removed daily (Archer, 1971).

Grass species used in the trial include seven varieties of perennial ryegrass, two types of timothy, orchardgrass, tall (Alta) fescue, red fescue S.59 (*Festuca rubra* L.), Canadian creeping red fescue, browntop (*Microstegium* Nees), Kentucky bluegrass, rough stalked meadow grass (*Poa trivialis* L.), crested dogstail (*Cynosurus cristatus* L.), meadow foxtail (*Alopecurus pratensis* L.), and sweet vernal (*Anthoxanthum odoratum* L.). Herbs used were ribgrass or plantain (*Plantago lanceolata* L.), chicory (*Cichorium intybus* L.), yarrow (*Achillea millefolium* L.), dandelion (*Taraxacum officinale* F.H. Wigg.), sheeps parsley (*Petroselinum crispum* Mill.), and burnet (*Poterium sanguisorba* Scop.). Legumes were wild white clover, late flowering red clover, sainfoin (*Onobrychis viciifolia* Scop.), and kidney vetch (*Anthyllis vulneraria* L.). Two grass mixtures consisted of 90% cocksfoot and 10% rough stalked meadow grass and a dryland mixture with differing ratios of perennial ryegrass, meadow fescue, cocksfoot, timothy, and two types of white clover. Amount of total time the horses spent on each species was combined over the two year grazing period, and grasses the horses spent the most amount of time grazing were concluded to be more palatable. The dryland mixture was shown to be the most readily preferred by the horses followed by some perennial ryegrass varieties, cocksfoot, timothy, and tall fescue (Archer, 1971). Archer (1971) concluded that a wide mixture of forage species could be appropriate for a horse pasture, and recommended experimenting between several palatable species such as the ryegrasses, timothy, crested dogstail, wild white clover, dandelion, ribgrass, chicory, yarrow, burnet, and sainfoin as well as palatable turf grasses including tall fescue, Canadian creeping red fescue, and smooth and rough stalked meadow grass.

In 1974, Archer (1978a) utilized twelve grass species replicated five times. The twelve grasses included creeping red fescue, Alta tall fescue, Canadian creeping red fescue, crested dogstail, cocksfoot, brown top, tall fescue, timothy, meadow foxtail, and three types of perennial ryegrass. Minimization of excretion which creates the “lawn” and “rough” grazing pattern of horses was attempted with removal of manure twice a day.

Horses typically do not eat where they defecate, and therefore, if left for long periods of time on the same pasture, the pasture will develop a lawn and rough pattern. Lawns are characterized as areas of shorter grass horses consume, while the roughs are taller, weedier areas where defecation usually occurs. Crossbred ponies and two thoroughbreds were grazed starting in September of 1974 with six more grazing periods thereafter. Grass was allowed to grow to 15cm before horses were allowed to graze. Horses grazed continuously until the grass was short, without being damaged. The horses were removed from the plots and measurements were taken on each grass species to determine height post-grazing.

Archer (1978a) determined that creeping red fescue and tall fescue were the most palatable, whereas meadow foxtail and the perennial ryegrasses were deemed less palatable. Grasses that were grazed down and exhibited poor growth, such as the crested dogstail, were also invaded by other species like the ryegrasses, timothy, and cocksfoot. However, the horses selectively chose the cocksfoot within the ryegrass. It was found that meadow foxtail and brown top became less palatable as they matured and that individual variation between horses and maturity levels of plants influenced the results. Based on the results, Archer (1978a) recommended that creeping red fescue be incorporated into equine pastures.

Archer (1980) concluded that hybrid ryegrass, Alta and Dovey tall fescue, creeping red fescue, and crested dogstail are highly palatable to horses and meadow foxtail, timothy, perennial ryegrass S24, cocksfoot, and tall fescue S53 were not favored. Other perennial grasses that were somewhat favored included perennial ryegrass, brown top, and Kentucky bluegrass. Even though forage qualities between grasses vary, low fiber, high carbohydrates, maturity, and texture may be a factor. Hybrids have shown potential even in the more mature, stemmy phases of growth; however, the hybrid ryegrass types were not persistent. The tall fescue was hard to develop and manage, but showed strong drought and excess moisture resistance.

Archer (1980) concluded that horse owners should plant seed mixtures in their horse paddocks, and recommended perennial ryegrass along with creeping red fescue and one variety based on climate or pasture use. Suggestions for the third variety included meadow grasses, timothy, cocksfoot, and tall fescue. Additionally, herbs such as cichory, plantain or ribgrass, dandelion, yarrow, burnet, and sheeps parsley could be added for variety and balance to the equine diet but clover should not be overplanted. Although Archer's publications are over 30 years old, his recommendations for pasture management still apply in the current equine industry. The specific grass species he used are outdated, but the research principles that were established are sound (Archer, 1980).

Hunt and Hay (1990) conducted a trial in New Zealand using deer, dairy beef calves, and mares. They planted four replicates of 16 forages (grasses, herbs, and legumes) beginning in 1988. Animals were grazed on the plots when the grasses reached approximately 15 cm in height. Grass preferences were analyzed and recorded using a photographic technique that had four automatic cameras mounted on poles 3 m in height. Each of the cameras recorded four treatment plots for 72 minutes with photos taken every 2 minutes. A total of 432 photographs were analyzed. Forages used in the trial included several species of ryegrass, two types of cocksfoot, prairie grass (*Bromus willdenowii* Kunth.), timothy, tall fescue , two red clovers, lotus (*Lotus corniculatus* L.), lucerne (*Medicago sativa* L.), two white clovers, sainfoin, sulla (*Hedysarum coronarium* L.), chicory, sheep's burnet (*Sanguisorba minor* Scop.), and common dock (*Rumex obtusifolius* L.).

Deer seemed to prefer red clover, while moderately selecting lotus, chicory, white clover, and sheep's burnet. They also preferred the legumes above the grass or dock species. The dairy beef calves, however, chose the cocksfoot above, followed by timothy, tall fescue, endophyte enhanced perennial ryegrass, prairie grass, and hybrid and low endophyte ryegrasses. The calves did not prefer the legumes and herbs. Finally, the horses selectively grazed the prairie grass and they also grazed well on all other species accept for the red clover, sainfoin, sulla, and sheep's burnet.

Hunt and Hay (1990) concluded that differences in forage preference exist between animal species, and that each species has a clear preference. They agreed with Archer (1973a) and concluded that ryegrasses were palatable, though different varieties were tested. Hunt and Hay (1990) also concluded that palatability was important to consider, especially in horses, since they are highly selective and discriminate against less palatable species in a pasture if given the choice.

McCann and Hoveland (1991) managed a palatability trial over a two year period in Georgia (1988 and 1989). They used five winter annual grasses and four clovers to determine horse forage preference. Species used included cool-season annual grains 'Stacey' wheat (*Triticum vulgare* Vill.), 'Simpson' oats (*Avena sativa* L.), 'Marshall' annual ryegrass (*Lolium multiflorum* Lam.), 'Morrison' triticale (*Triticosecale rimpaui* Wittm.), and 'Wintergrazer 70' rye (*Secale cereal* L.). The clovers included 'Tibbe' crimson clover (*Trifolium incarnatum* L.), 'Yuchi' arrowleaf clover (*Trifolium vesiculosum* Savi.), 'Mt. Barker' subterranean clover (*Trifolium subterraneum* L.), and 'Bigbee' berseem clover (*Trifolium alexandrinum* L.). Grass plots were planted in separated areas in a randomized complete block design with six replications. The pasture was tilled, limed, and fertilized before planting began each September with nitrogen being spread at planting and again in November, January, and March of each year. Eight to 10 quarter horse yearlings were grazed for four hours each at each grazing date. The trial was completed once the majority of grass in the plots was consumed. Feces were removed after each trial, and strips of the grazed plots were harvested to analyze residual forage.

Annual ryegrass was the most preferred grass and was selectively grazed by the yearlings, following ryegrass, oats and wheat were found to be preferred, and rye and triticale tended to be the least preferred. Of the clovers, only the arrowleaf clover was not consumed and was deemed highly unpalatable. This was assumed to be due to the high tannin levels in arrowleaf, especially as it matures, which horses do not tolerate well. McCann and Hoveland (1991) agreed with Archer (1973a, 1978) and Hunt and Hay (1991) and concluded that forages provide an important source of nutrition and that palatability should be considered with both legumes and herbs incorporated into pastures to maximize horse use.

In a study on feral horses and cattle conducted by Krysl et al. (1984) in the Red Desert of Wyoming, horses and cattle were confined to a test area of 252 ha for several months during the summer, and a 120 ha pasture for a month in the winter to promote species competition between the animals. Observations were taken and fecal samples were collected to determine species of forage consumed. The animals were allowed to graze on the available natural forages. Major species present during the summer (described as a sagebrush-grass range) included big sagebrush (*Artemisia tridentata* Nutt. subsp. *vaseyanu* Rydb., *wyomingensis*), Douglas rabbit-brush (*Chrysothamnus viscidiflorus* Nutt.), winterfat (*Ceratoides lanata* Pursh.), and gray horsebrush (*Tetradymia canescens* DC.), needleandthread (*Hesperostipa comata* Trin. & Rupr.), thickspike wheatgrass (*Elymus lanceolatus* Scribn. & J.G. Sm.), Indian ricegrass (*Achnatherum hymenoides* Roem. & Schult.), needleleaf sedge (*Carex duriuscula* C.A. Mey.), prairie Junegrass (*Koeleria macrantha* Ledeb.), locoweed (*Astragalus mollissimus* Torr., now known to be poisonous) and hoods phlox (*Phlox hoodia* Richardson).

The upland range site (described as a saltbush), included nuttall saltbush (*Atriplex nuttalli* S.), bud sagewort (*Artemisia spinescens* Nutt.), birdfoot sagebrush (*Artemisia pedatifida* Nutt.), Sandberg blue-grass (*Poa secunda* J. Presl), bottlebrush squirreltail (*Elymus elymoides* Raf.), winterfat, and greenmolly summercypress (*Bassia americana* S. Watson). Additional species scattered throughout the study area included greasewood (*Sarcobatus vermiculatus* Hook.), rubber rabbitbrush *(Ericameria nauseosa* Pall. ex Pursh), fourwing saltbush (*Atriplex canescens* Nutt.), spiny hopsage (*Grayia spinosa* Moq.), Sandberg bluegrass, Indian ricegrass, needleandthread, lambsquarter (*Chenopodium album* L.), western dock (*Rumex aquaticus* L.) and scurfpea (*Cullen* Medik.).

Researchers concluded that horses tended to select primarily grasses and sedges such as needleleaf sedge, Indian ricegrass, prairie Junegrass, thickspike wheatgrass, Sandberg bluegrass, bottlebrush squirreltail, and needleandthread. Other shrubs and herbs were grazed, and at the end of the summer, horses grazed the remaining grasses. Cattle grazed more of the sedges and herbs and consumed an overall broader spectrum of plants compared to the horses. It was concluded that due to competition, dietary overlap was observed between the two species.

A more recent, smaller scale project was conducted by Wilson at Ohio State University in 2006. The research objective was to observe equine grazing preferences of different grass species. Four grass varieties ('Tetraplus' perennial ryegrass, 'Cambia' orchardgrass, 'Tekapo' orchardgrass and 'Duo'festulolium (*Festulolium braunii* A. Camus)) were planted in a quadrant pattern with three replications in 1/3 acre paddocks. Two horses were grazed per paddock for one hour in the morning and one hour in the afternoon during three separate grazing occasions (one for each spring, summer, and fall). Orchardgrass varieties tended to be the most preferred by the horses in the morning. In the afternoon horses preferred perennial ryegrass, 'Cambia' orchardgrass, festuloium, and 'Tekapo' orchardgrass. Overall, orchardgrass was found to be the most preferred followed by the ryegrass, and then festuloium. If data was separated by month, the June mornings found horses choosing each species relatively equally. In August and October mornings, horses were more likely to graze the orchardgrass, then the festuloium, and finally the ryegrass. June afternoons however, showed that horses seemed to prefer the ryegrass and festuloium over the orchardgrass although this could be due to orchardgrass being grazed down in the mornings. During August afternoons, horses again liked the orchardgrasses, then the ryegrass, and finally the festuloium (Wilson, 2006).

While there is evidence illustrating equine forage preferences more research is needed on equine grazing patterns and proper management of equine pastures.

Feed Intake in Horses

An important factor for horse owners to consider is feeding behaviors that are specific to horses. However, forage quality should also be considered. Marten (1978) defines palatability or relative forage palatability as "a plant characteristic eliciting a proportional choice among two or more forages conditioned by plant, animal and environmental factors which stimulate a selective intake response by the animal". This attribute may also be described in terms of acceptability, preference, selective grazing, etc. (Marten, 1978). Marten (1978) goes on to conclude that palatability is more a factor of available choices, intake controlling mechanisms, and regulators in the brain than actual taste of a forage or feed. In addition, there is initial palatability and adapted palatability. Initial palatability is measured over a short amount of time and adapted palatability is measured over a longer period. Marten (1978) also concludes that palatability is a complex phenomenon determined by the animal, by the plants offered to the animal, and by the environment in which the selection occurs. The animal factors of palatability include the senses, species or breed, individual variation, previous experience or adaptation, and physiological condition. Plant factors include species, intraspecific variation, chemical composition, morphology or physical traits, succulence or maturation, grass availability in free grazing situations, and form of the forage controlled by mechanization such as mowing or fertilization. Environmental factors were plant diseases, soil fertility, manure, feed additives, climatic variation, and seasonal or diurnal variations (Marten, 1978).

It is not entirely known why animals, namely horses, find one species of grass or type of forage more preferable than another. McAnn and Hoveland (1991) state that forage maturity is an obvious factor of palatability, and younger plants should be more preferred over more fibrous, older plants. In addition, they indicate that a higher level of tannin in plant, which increases with temperature, is associated with lowered palatability. Higher nitrogen use (in fertilizer) may increase selection of less palatable grass species such as reed canarygrass and bermudagrass (*Cynodon dactylon* L.) (McAnn and Hoveland, 1991). If given no choice horses will eat whatever they are presented with as the survival instinct drives them to maintain body weight even when large selection of feed is not an option (Ralston, 1986). Hunt (1994) found that horses will select less mature, faster growing grasses, while Rogalski (1984) theorized that horses possibly choose forage based on higher sugar content rather than lower lignin content. Additionally, horses have been known to prefer variety in their diet and there is evidence to suggest that constant feeding of the same diet possibly lowers feed intake (McGreevy et al., 1995). Moreover, horses raised on, or adapted to, a specific diet with certain tastes and textures will tend to prefer that diet over another novel diet. For example, if a horse is moved to a new region and provided feed that varies from their native diet, a horse may reject the new feed (NRC, 2007). This is one reason why a period of acclimation is recommended in order to adapt horses a novel feed or diet (NRC, 2007).

If given the opportunity, horses will spend about 10 to 12 hours each day foraging, feeding more in the early morning and evening hours. Horses do not voluntarily fast for more than 3 to 4 hours and are assumed to regulate their own body weights by consuming 2 to 3% of their BW daily. Dry matter intake (DMI) is influenced by caloric density of a feed, and if it is below 0.5 kcal/kg of dry matter per day, it is not sufficient for the average horse to maintain weight. In current management scenarios, horses are restricted to stalls or only allowed access to feed for limited time throughout the day. Even if their caloric needs are met, in this short time, horses will still exhibit the urge to feed which can lead to habits such as cribbing or wood chewing (Ralston, 1986).

In a more recent analysis of pastures for horses, Hoskin and Gee (2004) claim that horses are more capable at utilizing forages low in nutrient value due to increased voluntary consumption compared to cattle. Even though cattle show increased dietary fiber degradation per unit of fiber, horses actually are more efficient per unit of time due to their increased DMI and rate of passage (Hoskin and Gee, 2004). Additionally, if growing horses are restricted in amounts of digestible energy, they will eat larger amount of dry matter on pasture, especially if forage quality is high. Horses rely on oropharyngeal and external stimuli to motivate them to graze or feed, more so than cattle or other ruminants (Hoskin and Gee, 2004). Grace et al., (2002a,b, 2003) found that for young thoroughbred horses and lactating mares in New Zealand on primarily a 0.2 to 0.25 ha ryegrass pasture (1,800-2,000 kg DM/ha) horses did not limit feed intake which were 5.5 kg DM/day, 6.9 kg DM/day, and 13.6 kg DM/day for weanlings, yearlings, and mares respectively. Hoskin and Gee (2004) also report that mares in lactation and gestation, and most young, growing horses are able to meet their energy requirements and obtain adequate levels of nutrition on high quality pasture grasses alone. However, the authors concluded that performance horses, due to their high amounts of work and exercise, require supplementation for extra energy and cannot be maintained on pasture or hay alone.

There are many advantages to keeping horses at pasture. They are less prone to colic (Hudson et al., 2001) or gastric ulcers (Murray, 1994) than horses housed in stalls. Horses with heaves that are confined to stalls or dry lots have limited feed that may only last a short time, and hay that is usually provided can cause chronic obstructive pulmonary disease (Derksen et al., 1985). Moreover, pastured horses have the ability to exhibit more natural behaviors, can voluntarily exercise, as well as engage in social interaction in the herd. They tend to show a lack of stereotypical behaviors such as cribbing or wind sucking (Pell and McGreevy, 1999). Horses on pasture are able to remain more mobile and have voluntary exercise which is essential for bone development in young colts (Bell et al., 2001). Finally, horse grazing patterns tend to influence pasture health and establishing varieties of grasses that can withstand both the pressure of horse grazing as well as being preferred by the horses are important for pasture health and maintenance as which benefits the animal as well.

Conclusion

Despite the copious amount of literature available on horse pasture management; there remains a lack of current research studying grass palatability and persistence under horse grazing. Though significant findings have been published over the last 50 years, the landscape of the forage and equine industry is constantly adapting and evolving. Palatability and forage quality of current grass species is needed and essential to advance ideal horse pasture management.

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Chapter 2

Yield and Persistence of Cool-Season Grasses Under Horse Grazing

E.M. Allen[1], K.L. Martinson[1], C.C. Sheaffer[2]

[1]Department of Animal Science, University of Minnesota, St. Paul, MN
[2]Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN

Chapter Summary

Most forage cultivars are not evaluated under livestock grazing. The objectives of this research were to evaluate forage yield and persistence of cool-season grasses under horse grazing. Research was conducted in 2010 and 2011 in which horses grazed 'Barolex' tall fescue (*Schedonorus phoenix* Scop.), 'Hidden Valley' meadow fescue (*Schedonorus pratensis* Huds.), 'Everett' quackgrass (*Elymus repens* L.), 'Agassiz' smooth bromegrass (*Bromus inermis* Leyss.), 'Fleet' and 'Paddock' meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.), 'Marathon' reed canarygrass (*Phalaris arundinacea* L.), 'Survivor' perennial ryegrass (*Lolium perenne* L.), 'Winneton' timothy (*Phleum pretense* L.), 'Ginger' Kentucky bluegrass (*Poa pratensis* L.), 'Garrison' creeping foxtail (*Alopecurus arundinaceus* Pior.), and 'Baridana' orchardgrass (*Dactylis glomerata* L.). Four adult horses grazed for eight hours a day for two days per month from May to October in 2010 and May to September in 2011. To determine persistence, ground cover prior to grazing was visually assessed as 0 (no ground cover) to 100 (100% ground cover), and yield was determined by harvesting prior to grazing. Orchardgrass, meadow fescue, Kentucky bluegrass and tall fescue were most persistent ($P \leq 0.05$), while timothy, meadow bromegrass, reed canarygrass, smooth bromegrass and creeping foxtail were less persistent ($P \leq 0.05$). Orchardgrass produced the highest yields ($P \leq 0.05$) with $\geq$ 10.1 Mt/ha, while creeping foxtail produced the lowest yield ($P \leq 0.05$) with $\leq$ 7.8 Mt/ha. Planting mixtures of Kentucky bluegrass, orchardgrass, and fescues should achieve a balance of forage persistence and maximum yield in Midwest U.S. horse pastures.

Key Words: horse, cool-season grass, persistence, yield

Introduction

In the U.S., approximately 23 million ha of cropland and 53 million ha of non-arable land, exclusive of range, are used for pasture (Vallentine, 1990). In the Midwest and Eastern U.S., cool-season grasses are the foundation of productive grass pastures. It is estimated that there are 9.2 million horses in the U.S. (AHS, 2007) and in a survey of Minnesota horse owners, 87% of respondents reported horses having access to pasture (Martinson et al., 2006). The selective nature and grazing habits of horses may limit the productivity and survival of some pasture species. Horses are known to be selective grazers and tend to over-graze preferred species before grazing other, less palatable species. Other livestock, such as cattle and sheep, tend to be less selective and are less likely to overgraze (Archer, 1973a). In addition, horses can graze species to a shorter height because they have prehensile lips and a tongue that pulls grass into the mouth (Archer, 1980).

Cool-season grass yield is dependent on many factors, including environment, agronomic management, and soil type and fertility. With multiple harvests, tall fescue (*Festuca arundinacea* Schreb.), meadow bromegrass (*Bromus riparius* Rehm.), and orchardgrass (*Dactylis glomerata* L.) had yields of 19.6, 17.3 and 17.0 Mt/ha, respectively, compared to smooth bromegrass (*Bromus inermis* Leyss.) and perennial ryegrass (*Lolium perenne* L.), which yielded less with 12.6 and 10.6 Mt/ha, respectively (Waldron et al., 2002). University yield trials have shown similar trends. Varieties of orchardgrass, tall fescue, meadow fescue (*Festuca pratensis*), reed canarygrass (*Phalaris arundinacea* L.), and meadow bromegrass produced yields greater than 9 Mt/ha, while varieties of Kentucky bluegrass (*Poa pratensis)*, timothy (*Phleum pretense*), perennial ryegrass, and smooth bromegrass tended to yield less (UK, 2011; UW, 2011).

Frequent forage removal to variable heights and hoof traffic create unique and stressful situations, however, the effect of livestock grazing on grass yield and persistence is rarely investigated (Deak et al., 2009). While recent research has focused on cool-season grass yield under livestock grazing in winter stockpiling systems (Volesky et al., 2008; Cuomo et al., 2005; Baron et al., 2005), little data is available on season-long yields and forage persistence under horse grazing.

Forage persistence is a major component of pasture productivity. Previous research has found that orchardgrass, tall fescue, and meadow fescue tolerate grazing well. Brummer and Moore (2000) observed good persistence of orchardgrass and tall fescue after grazing by beef cattle. Olson et al. (2011) observed 99 to 100% tall fescue ground cover after two years of intensive grazing by horses, and after two-years of multiple harvests, Brink et al. (2010) observed 91% ground cover with meadow bromegrass. Other grasses have demonstrated poor tolerance under livestock grazing, including timothy, festuloliums (*Festulolium braunii)*, reed canarygrass and smooth bromegrass (Olson et al., 2011; Brummer and Moore, 2000; and Riesterer et al., 2000). Some species had mixed persistence results when grazed by livestock, including perennial ryegrasses and Kentucky bluegrasses (Olson et al., 2011).

Forage grass yield and persistence are important factors to consider in a productive grazing system, especially when selecting grasses for use in pastures housing highly selective livestock like horses. However, many forage grasses have not been evaluated under horse grazing. The objectives of this research were to evaluate forage yield and persistence of cool season grasses while grazed by horses.

Materials and Methods

Research was conducted in St. Paul, MN in 2010 and 2011 using stands of grasses established in August 2009. The experimental design was a randomized complete block with four replications, with individual plots sizes of 3 x 6 m. Each replication contained twelve cool-season grass monocultures. Grasses included 'Barolex' tall fescue (*Schedonorus phoenix* Scop.), 'Hidden Valley' meadow fescue (*Schedonorus pratensis* Huds.), 'Everett' quackgrass (*Elymus repens* L.), 'Agassiz' smooth bromegrass (*Bromus inermis* Leyss.), 'Fleet' and 'Paddock' meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.), 'Marathon' reed canarygrass (*Phalaris arundinacea* L.), 'Survivor' perennial ryegrass (*Lolium perenne* L.), 'Winneton' timothy (*Phleum pretense* L.), 'Ginger' Kentucky bluegrass (*Poa pratensis* L.), 'Garrison' creeping foxtail (*Alopecurus arundinaceus* Pior.), and 'Baridana' orchardgrass (*Dactylis glomerata* L.). Grasses were fertilized with 56 kg N per hectare in early April and again in mid-June in both 2010 and

2011. Soil pH was 6.6, P was 18 ppm, and K was 85 ppm, and no soil amendments were required. Soil type was a Waukegan silt loam (fine-silty over skeletal, mixed, superactive, mesic Typic Hapludoll).

Grasses were evaluated for maturity and ground cover, measured for yield, and grazed by horses when most tall growing grasses reached 20 cm. At initiation of grazing, Kentucky bluegrass height averaged 10 cm. Yields were measured on 29 April, and immediately before grazing on 17 May, 14 June, 19 July, 16 August, 13 September, and 11 October in 2010; and on 17 May, 14 June, 12 July, 16 August, and 13 September in 2011. Lack of rainfall and re-growth prevented data collection in October 2011. Pre-grazing yields were measured by mechanically harvesting a 1 x 5 m area to a 9 cm height in each plot using a flail harvester (Carter Manufacturing Company, Inc., Brookston, IN). Yield areas were harvested from alternate sides of each plot each month to even the effect of harvesting and grazing on the entire plot. A forage subsample was manually collected to a 9 cm height from two 0.25 m^2 areas before harvesting, and dried at 35 ˚C for 24 hours to determine dry matter content; wet forage yields were then adjusted and are presented on a dry matter basis.

The remaining, un-harvested area of each plot was grazed by four adult horses (mean weight of 538 kg BW and 21 years in 2010 and 477 kg BW and 24 years in 2011) for eight consecutive hours beginning the day after yield harvest. To maximize forage utilization, horse grazing was restricted to two replicates each day using portable fencing. Following grazing, the remaining forage was mowed to a 9 cm height and allowed to re-grow. The same procedure was followed each month of grazing during 2010 and 2011. All experimental procedures utilizing horses were conducted according to those approved by the University of Minnesota Committee on Animal Use and Care. Before each grazing, and in April 2012, plots were visually assessed for percent ground cover on a scale of 0 (bare ground) to 100 (100% ground cover of desired species) to assess forage persistence, and maturity was evaluated using a scale developed by Moore et al. (1991).

Data were analyzed using the ANOVA and MIXED procedures of SAS (SAS Inst. Inc., Cary, NC; version 9.2). Plots were the experimental units and statistical significance was set at $P \leq 0.05$. Means are the least square means of the ANOVA and

MIXED procedures. Grass species and months were designated as fixed effects. Years were different ($P \leq 0.05$), thus results for each year are presented seperately. Although grazing occurred at monthly intervals, data was analyzed represented as climatological season including spring (April and May), summer (June and July) and fall (August, September, and October) for yield. Data for persistence was analyzed as spring (May), summer (July), and fall (September), with the exception of 2012, where April represents Spring (grazing was not initiated in 2012); other months were not included in the data analysis. Results for 'Fleet' and 'Paddock' meadow bromegrass were not different ($P \geq 0.05$), thus data were combined and are reported as meadow bromegrass.

Results and Discussion

Precipitation and Temperature

During the 2010 and 2011 grazing season (May through October), average air temperatures were near historical averages (Table 1.1). More rainfall was recorded during both grazing seasons compared to the historical average. In 2010, rainfall observed in July through September exceeded historical average by almost 17 cm, and the 2010 grazing season ended with almost 11 cm more rainfall compared to the historical average. Two drier than normal fall months in 2011 (September and October) resulted in an inability to graze in October of 2011.

Maturity

Cool-season grass maturity was different ($P \leq 0.0001$) among species and years, however, similar trends were observed each year (Table 1.2). During the spring of both years, creeping foxtail was more mature ($P \leq 0.05$) compared to all other grasses except meadow bromegrass in spring 2010. Maturity of creeping foxtail ranged from boot stage (3.0; Moore et al., 1991) in 2011 to spikelets fully emerged (3.3) in 2010. All others grasses were in the early stem elongation phase with few differences in maturity.

During the summer of both years, perennial ryegrass was more mature ($P \leq 0.0001$) compared to all other grasses. Maturity of perennial ryegrass ranged from spikelet visible (3.2) in 2011 to inflorescence emerged (3.5) in 2010. Meadow bromegrass, quackgrass, reed canarygrass, and smooth bromegrass were in the stem elongation stage during the summer and fall months of 2010 and 2011. Timothy matured to the boot stage in the summer of 2010 but remained in the stem elongation phase in the summer of 2011. During the summer and fall of both years, Kentucky bluegrass, orchardgrass, meadow fescue, and tall fescue remained in the vegetative stage.

Differences observed in plant maturity throughout the grazing season are likely due to varietal differences and environmental conditions. Due to reproductive day-length requirements, only one major set of seed heads are produced each year for cool-season grasses (Moser and Hoveland, 1996), usually occurring during the spring in the Midwest U.S. For the remainder of the growing season, cool-season grasses tend to remain vegetative (Moser and Hoveland, 1996). This corresponds to observations recorded in the current study.

Persistence

Grasses differed in their persistence under horse grazing; however, most differences were seen during the second year of grazing ($P \leq 0.0006$; Table 1.3). At the initiation of grazing in 2010 (spring), all grasses had stands of greater than 80% ground cover except timothy, which had 55% ground cover. By summer, all grasses had greater than 97% ground cover, with most grasses having 100% ground cover. In the fall of 2010, creeping foxtail had 55% ground cover. This was less than ($P \leq 0.0001$) the other grasses, except timothy, which had greater than 83% ground cover.

In the spring of 2011, meadow fescue, Kentucky bluegrass, and orchardgrass had greater than 88% ground cover which exceeded ($P \leq 0.0001$) that of smooth bromegrass, reed canarygrass, and creeping foxtail, which had 64% ground cover. No differences were observed between the other grass species. A similar trend continued through the summer of 2011, however, quackgrass ground cover was equal ($P \geq 0.05$) to meadow fescue and orchardgrass, with greater than 91% ground cover. Smooth bromegrass, reed canarygrass and creeping foxtail resulted in reduced ground covers ($P \leq 0.05$) ranging from 59 to 45%. No differences were observed between the other grass species. By fall 2011, tall fescue, Kentucky bluegrass, meadow fescue, and orchardgrass had ≥85%

ground cover, which was greater than all other species (*P* ≤ 0.0001). Creeping foxtail, meadow bromegrass, and smooth bromegrass were among the grasses that had less ground cover (*P* ≤ 0.0001). In spring 2012, Kentucky bluegrass, meadow fescue, orchardgrass, and tall fescue were the most persistent (*P* ≤ 0.05) species with greater than 78% ground cover. Creeping foxtail and smooth bromegrass were the least persistent grasses (*P* ≤ 0.0001) with less than 14% ground cover, however, reed canarygrass and timothy also showed reduced persistence with 24% ground cover.

During the grazing seasons of 2010 and 2011, orchardgrass, tall fescue, meadow fescue and Kentucky bluegrass were the most persistent grasses. Previous researchers have also determined orchardgrass to be persistent (Washko, 1967; Jung et al., 1974; and Van Santen and Sleper, 1996). In Kentucky, orchardgrass grazed by horses for two years had ground cover of 92 to 84%, (Olson et al., 2011). Brummer and Moore (2000) determined that tall fescue persisted well, resulting in 82 and 71% ground cover after the first and second years, respectively, of continuously grazing beef cattle. Persistence of meadow fescue in our study was almost identical to that of Brink et al. (2010) who observed 91% ground cover after two years of multiple mechanical harvests. Ground cover observed for Kentucky bluegrass was different than that reported by Olsen et al. (2011) who found ground cover ranged from 70 to 79% after two years of continuous grazing by horses. The differences in persistence observed in Kentucky bluegrass between the current study and Olsen et al. (2011) are likely due to differences in grazing systems, locations, and varieties.

In the current study, perennial ryegrass and quackgrass had moderate persistence with 82 and 78% ground cover, respectively, after two years of grazing. The results of the current study mirror those of Olson et al. (2011) who classified perennial ryegrass as moderately persistent under intense horse grazing, and observed 79 to 81% ground cover. Riesterer et al. (2000) found quackgrass persistence to be moderate (88% ground cover) under a simulated grazing (i.e. mechanical harvest) system, however, ground cover was reduced to 65% when quackgrass was grazed (Riesterer et al., 2000).

Creeping foxtail, meadow bromegrass, reed canayrgrass, smooth bromegrass and timothy were among the less persistent grasses in our study. McCartney and Bittman

(1994) found that smooth bromegrass and meadow bromegrass persisted moderately in a four year cattle grazing study under various grazing intensities, averaging 62 and 56% ground cover in the first year, respectively, and steadily declined to 46 and 28%, respectively, by the fourth year of grazing. Brummer and Moore (2000) found that smooth bromegrass ground cover was 9 and 6%, respectively, after one and two seasons of continuously grazing beef cattle. However, Casler et al. (1998) found that smooth bromegrass stands were improved to 60 to 70% ground cover when rotational grazing was implemented with dairy cattle. Marten and Hovin (1980) determined that smooth bromegrass persistence was affected by number of harvests, and persistence was lowest after four harvests (40% ground cover) and increased to 76% ground cover when the harvest number was reduced to three.

Reed canarygrass persistence also appears to be affected by differences in cutting and grazing management. Marten and Hovin (1980) reported that reed canarygrass persistence was excellent, and ranged from 100 to 94% with two to four cuttings, respectively. However, under continuous grazing by beef cattle, Brummer and Moore (2000) observed that reed canarygrass ground cover was reduced to 7 and 10% after one and two years of continuous grazing, respectively. In the current study, reed canarygrass stands were reduced to 60% ground cover after two years of rotational grazing, which is similar to Casler et al. (1988) who found 60 to 70% ground cover after two years of rotational grazing. Similar to reed canarygrass and smooth bromegrass, timothy persistence under livestock grazing has been previously described as low. The results for timothy in the current study agree with that of Riesterer et al. (2000) who found that timothy had the lowest ground cover in the fall compared to other cool-season grasses after two years of grazing. Based on these results, creeping foxtail, reed canarygrass, smooth bromegrass and timothy would not be the ideal choice for cool-season grass use in a horse grazing system.

Many researchers agree that most varieties of reed canarygrass, smooth bromegrass and timothy will not persist well if cut or grazed during the stem elongation phase (Vogel et al., 1996), due to depletion of carbohydrate root reserves and removal of shoots and tillers that contribute to re-growth (Marten and Hovin, 1980). Compared to the more persistent species of orchardgrass and tall fescue that have culmless vegetative shoots, reed canayrgrass, smooth bromegrass, and timothy have culmed vegetative shoots and continue to elongate in re-growth cycles (Reynolds and Smith, 1962). Current equine grazing recommendations include initiating grazing of tall, cool-season grass pastures at a plant height of 15 to 20 cm. This recommendation will likely place pastures containing reed canarygrass, smooth bromegrass and timothy at the stem elongation stage at the start of grazing, making these plants particularly vulnerable to carbohydrate depletion, thus resulting in stand thinning. Grazing initiation should either be managed to avoid the stem elongation stage in these species, or these grasses should not be included in intensively grazed pasture systems.

Yield

Total forage yields were different among grasses during 2010 and 2011 however, the same yield trends were observed among the grasses in both years (Table 1.4). In both 2010 and 2011, orchardgrass was the highest yielding grass ($P \leq 0.0001$) with 13.9 and 10.1 Mt/ha, respectively, while creeping foxtail was the lowest yield grass ($P \leq 0.0001$) with 7.8 and 5.0 Mt/ha, respectively. In 2011, tall fescue, meadow bromegrass, and reed canarygrass had yields similar to orchardgrass ($P \geq 0.0001$). In 2010, Kentucky bluegrass, quackgrass, timothy and smooth bromegrass had yields similar to creeping foxtail ($P \geq 0.0001$), while timothy and smooth bromegrass had similar yields to each other in 2011 ($P \geq 0.0001$). Differences between total yields in 2010 and 2011 were likely due to the number of harvests and weather conditions. An early spring, followed by a wet fall, allowed for seven months of yield collection in 2010 (April through October). In 2011, the first harvest occurred in May and a dry fall resulted in a lack of yield collection in October, for a total of five months of yield collection in 2011.

These results agree with Marten and Hovin (1980) and Jung et al. (1974) who found that orchardgrass and tall fescue yield was maximized with multiple harvests, yielding approximately 10 Mt/ha in multiple cut systems, making these species ideal pasture grasses. Although not a top yielding species in this study, a similar trend was also observed in Kentucky bluegrass with yields approaching 7 Mt/ha in an eight cut system (Jung et al., 1974), similar to yields observed in 2011. Marten and Hovin (1980) found reed canarygrass had a three year yield average of 10.5 Mt/ha. However, in the current study, reed canarygrass had moderate yields in 2010 and 2011; however, ground cover was reduced to 24% by the spring of 2012, which contributed to the lower yields. Jung et al. (1974) observed a similar trend with reed canarygrass yield decreasing as cutting frequency increased. These results suggest the long-term persistence, and thus yield potential, of reed canarygrass under livestock grazing is likely reduced.

Moderate yielding species in the current trial included meadow fescue, perennial ryegrass, Kentucky bluegrass, and quackgrass, with yields ranging from 6.8 to 10.1 Mt/ha. This is similar to yields observed by Sheaffer et al. (1990) who found that quackgrass yielded 6.5 Mt/ha in a four-cut system, and had similar yields compared to that of reed canarygrass and smooth bromegrass. Casler and Goodwin (1998) also concluded quackgrass yield was moderate compared to other species with varieties ranging from 7.56 to 7.77 Mt/ha. However, similar to results of reed canarygrass, the long-term persistence and yield potential of quackgrass under horse grazing is uncertain due to reduced persistence. Meadow fescue, as described by Casler et al. (2008), has recently been rediscovered with cultivars released for use in grazing systems. Although yields of "Hidden Valley" meadow fescue were less than orchardgrass ground cover was always similar between the species, highlighting the potential use of meadow fescue as a top performing grass in horse pasture mixes.

Low yielding grasses in the current study included creeping foxtail, smooth bromegrass and timothy. Marten and Hovin (1980) found that smooth bromegrass had the lowest three year yield average of 8.9 Mt/ha when compared to reed canarygrass, tall fescue and orchardgrass. Jung et al. (1974) determined that smooth bromegrass yield decreased to approximately 5 Mt/ha as the number of cuttings increased from three to eight. In a three year study, Angima et al. (2009) found that timothy averaged about 4 Mt/ha when harvested in the spring which is comparable to spring yields of timothy in 2010 but higher than timothy yields from 2011. All three lower-yielding grasses produced more yield during the first year of grazing, but poor persistence during the second year of grazing led to reduced yields. These data suggest that creeping foxtail, smooth bromegrass and timothy will persist and yield better with fewer harvests; however, this management scheme is not practical in a livestock grazing system.

Seasonal yield distribution is shown in Figures 1.1 and 1.2. In both 2010 and 2011, the majority of yield for each grass was harvested during the summer months of June and July with percentages ranging from 32% to 74% of total yield. During 2010, grass yield was more evenly distributed between spring and summer. In 2011, spring yield component ranged from 27% to 46%, while summer months contributed 49 to 74% of the yield. Fall of 2010 contributed the lowest amount of the total yield, and ranged from 18% to 27%. Denison and Perry (1990) also found that fall growth rates were generally less than or equal to summer months when rainfall was adequate throughout the grazing season. In 2011, both spring and fall contributed lesser amounts to total yield compared to the summer months.

Generally, cool-season grasses grow well between 20 and 25°C (Moser and Hoveland, 1996), with a majority of yield produced during the spring and fall when temperatures are cooler and moisture supply is adequate. Most cool-season grasses experience a reduction in production during the traditionally warmer and drier summer months which has been termed the ‘summer slump’ (Riesterer et al., 2000). Chamblee and Spooner (1985) showed lower summer growth rates for orchardgrass and tall fescue in North Carolina, and Wolf et al. (1979) reported a continuous decline in the growth rate of tall fescue during spring and summer months in Virginia with a dramatic recovery during the fall (Wolf et al., 1979). Engel et al. (1987) determined that smooth bromegrass normally produces the majority of its seasonal growth in early spring when leaf area, light interception, and growth rate are at a maximum, with production declining during the summer when these factors are reduced.

However, other researchers in more northern regions have demonstrated little evidence of a summer slump in tall fescue, Kentucky bluegrass, orchardgrass, reed canarygrass, smooth bromegrass and timothy (Jung et al., 1974). In a pasture system, grasses are frequently grazed and managed to remain in a vegetative stage, allowing for similar amounts of leaf area, light interception and growth rates throughout the season.

This management scheme combined with above average rainfall observed in the spring and summer of 2010 and 2011 likely explains the increase in production observed during the summer months of both years and the lack of a ‘summer slump’.

Conclusions

Under horse grazing, orchardgrass, meadow fescue, tall fescue, and Kentucky bluegrass were the most persistent and highest yielding grasses, while smooth bromegrass, creeping foxtail, and timothy were the least persistent and lowest yielding species. Mixtures of orchardgrass, fescues, and Kentucky bluegrass should be planted in Midwest horse pastures; however, information on equine preference and forage quality should also be taken into consideration when planning a horse pasture.

Table 1.1. Average temperature (°C) and precipitation (cm) for St. Paul by month and year.

		Temperature				Precipitation	
Year	**Month**	**High**	**Low**	**Average**	**Departure from historical average**[†]	**Total**	**Departure from historical average**
		°C				cm	
2010	May	34.4	0.0	15.2	+0.3	5.9	-3.5
	June	31.1	10.0	19.3	-0.7	15.1	+2.4
	July	32.8	15.0	23.1	+0.6	13.9	+2.7
	August	33.3	10.6	23.3	+2.1	17.8	+6.7
	September	28.3	2.8	14.4	-1.7	13.0	+4.9
	October	30.0	-3.3	11.1	+1.6	3.9	-2.4
2011	May	30.0	-1.1	13.3	-1.6	11.2	+1.7
	June	38.3	8.3	19.3	-0.7	10.9	-1.8
	July	36.1	13.3	24.7	+2.2	26.4	+15.2
	August	32.2	12.2	21.7	+0.5	14.2	+3.1
	September	32.2	0.6	15.9	-0.3	1.7	-6.4
	October	30.0	-2.8	11.8	+2.4	2.0	-4.3

[†] Climate data obtained from http://climate.umn.edu/doc/historical.htm

Table 1.2. Stages of maturity for cool-season grasses during the 2010 and 2011 grazing season.

Species	2010 Spring[†]	2010 Summer	2010 Fall	2011 Spring	2011 Summer	2011 Fall
	- -	- - Index[‡] - -				- -
Creeping Foxtail	3.3[a]	2.8[b]	2.4[a]	3.0[a]	2.6[bc]	2.3[a]
Kentucky Bluegrass	2.7[bc]	1.5[c]	1.3[c]	2.7[b]	1.4[d]	1.3[b]
Meadow Bromegrass	3.1[ab]	2.8[b]	2.5[a]	2.6[bc]	2.6[c]	2.4[a]
Meadow Fescue	2.4[c]	1.7[c]	1.4[bc]	2.4[cd]	1.4[d]	1.4[b]
Orchardgrass	2.3[c]	1.6[c]	1.6[b]	2.6[bcd]	1.5[d]	1.4[b]
Perennial Ryegrass	2.3[c]	3.5[a]	2.4[a]	2.3[d]	3.2[a]	1.3[b]
Quackgrass	2.5[c]	2.9[b]	2.4[a]	2.5[bcd]	2.7[bc]	2.3[a]
Reed Canarygrass	2.5[c]	2.9[b]	2.6[a]	2.6[bc]	2.9[b]	2.5[a]
Smooth Bromegrass	2.6[c]	2.9[b]	2.5[a]	2.6[bc]	2.7[bc]	2.6[a]
Tall Fescue	2.3[c]	1.6[b]	1.4[bc]	2.5[cd]	1.4[d]	1.5[b]
Timothy	2.4[c]	3.0[b]	2.4[a]	2.6[bcd]	2.5[c]	2.3[a]
SEM	*0.1*	*0.1*	*0.1*	*0.1*	*0.05*	*0.1*
P-value	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*

[†] Spring values refer to data collected in May, Summer from July, and Fall from September

[‡] Numerical index referring to stage of grass development (Moore, K., L. Moser, S. Waller, and K. Vogel. 1991. Staging perennial forage grasses. Crop Prod. News. 11(13). Emergence of first leaf or first phase of Vegetative Stage is equal to 1.0, onset of stem elongation is equal to 2.0, boot stage is equal to 3.0, and caryopsis visible is equal to 4.0.

[a-d]Mean separations are within columns and years. Values with the same letter are not significantly different ($P \leq 0.05$).

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Table 1.3. Persistence of cool-season grasses under horse grazing during the 2010, 2011, and 2012 grazing season.

	2010			2011			2012
Species	**Spring†**	**Summer**	**Fall**	**Spring**	**Summer**	**Fall**	**Spring‡**
	% ground cover§						
Creeping Foxtail	81[b]	100[a]	55[b]	64[b]	45[c]	25[bc]	2[f]
Kentucky Bluegrass	80[b]	97[b]	86[a]	88[a]	89[ab]	85[a]	90[a]
Meadow Bromegrass	82[ab]	100[a]	85[a]	84[ab]	77[ab]	29[bc]	42[c]
Meadow Fescue	93[ab]	100[a]	88[a]	90[a]	91[a]	89[a]	78[ab]
Orchardgrass	93[ab]	100[a]	86[a]	90[a]	94[a]	93[a]	79[a]
Perennial Ryegrass	98[a]	100[a]	83[a]	78[ab]	88[ab]	78[a]	61[b]
Quackgrass	83[ab]	100[a]	90[a]	71[ab]	91[a]	75[a]	40[cd]
Reed Canarygrass	85[ab]	100[a]	89[a]	64[b]	59[bc]	51[b]	24[de]
Smooth Bromegrass	89[ab]	100[a]	84[a]	64[b]	45[c]	24[c]	14[ef]
Tall Fescue	93[ab]	100[a]	91[a]	80[ab]	81[ab]	84[a]	79[a]
Timothy	55[c]	97[b]	78[ab]	78[ab]	66[abc]	49[b]	24[de]
SEM	*3*	*0.5*	*5*	*5*	*6*	*5*	*3*
P-value	*<.0001*	*<.0001*	*0.0005*	*0.0006*	*<.0001*	*<.0001*	*<.0001*

[a-c] Mean separations are within columns and years. Values with the same letter are not significantly different ($P \leq 0.05$).

† Spring values refer to data collected in June, Summer from July, and Fall from September.

‡ Spring 2012 values refer to data collected in April.

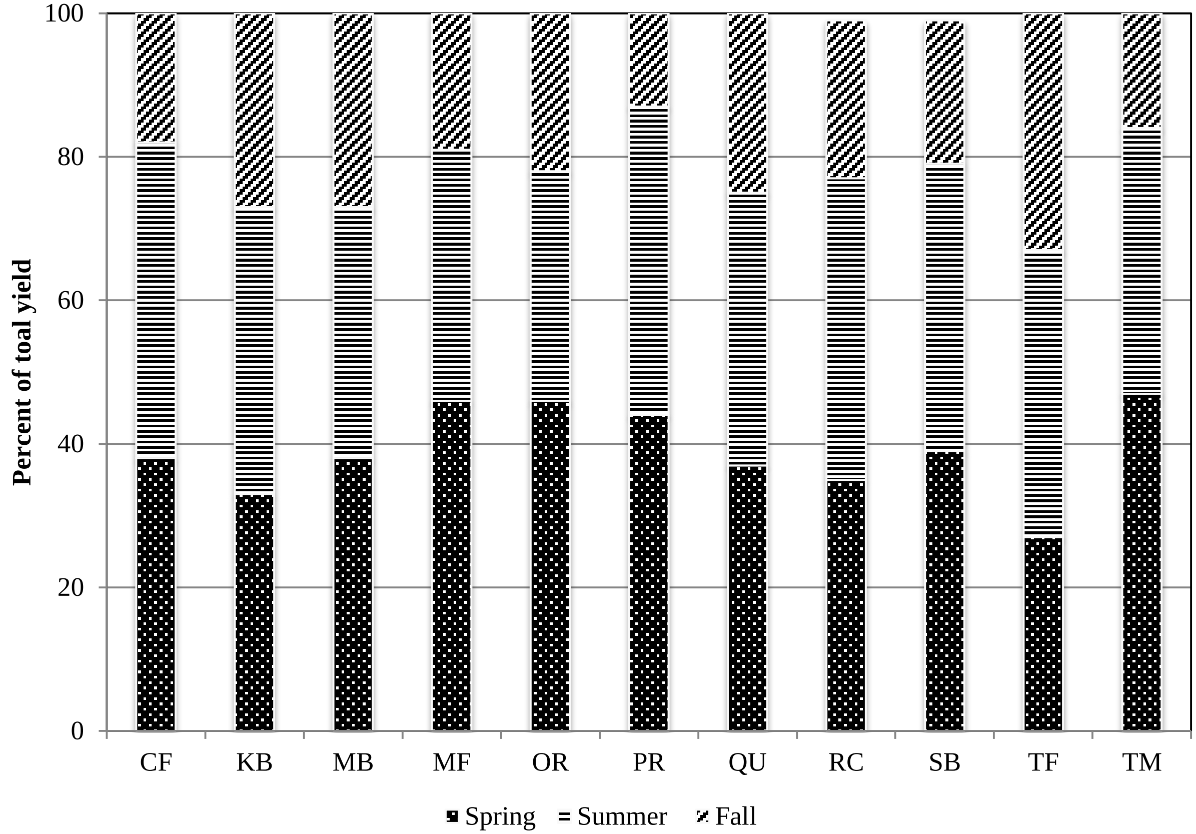
§ Persistence assessed as percent ground cover ranging from 0 (bare ground) to 100 (100% ground cover by identified species).

Table 1.4. Total yield for cool-season grasses for the 2010 and 2011 grazing season.

	2010		**2011**
Species	**Mt/ha**	**Species**	**Mt/ha**
Orchardgrass	13.9^{a}	Orchardgrass	10.1^{a}
Tall Fescue	11.1^{b}	Meadow Fescue	9.6^{ab}
Meadow Bromegrass	10.9^{b}	Tall Fescue	9.2^{ab}
Reed Canarygrass	10.5^{b}	Kentucky Bluegrass	8.5^{abc}
Meadow Fescue	10.1^{bc}	Quackgrass	8.2^{bc}
Perennial Ryegrass	9.9^{bc}	Perennial Ryegrass	7.3^{cd}
Kentucky Bluegrass	9.4^{bcd}	Reed Canarygrass	6.9^{cd}
Quackgrass	9.4^{bcd}	Meadow Bromegrass	6.8^{cd}
Timothy	8.7^{cd}	Timothy	6.4^{de}
Smooth Bromegrass	8.6^{cd}	Smooth Bromegrass	6.1^{de}
Creeping Foxtail	7.8^{d}	Creeping Foxtail	5.0^{e}
SEM	*0.7*		*1.2*
P-value	*<.0001*		*<0.0001*

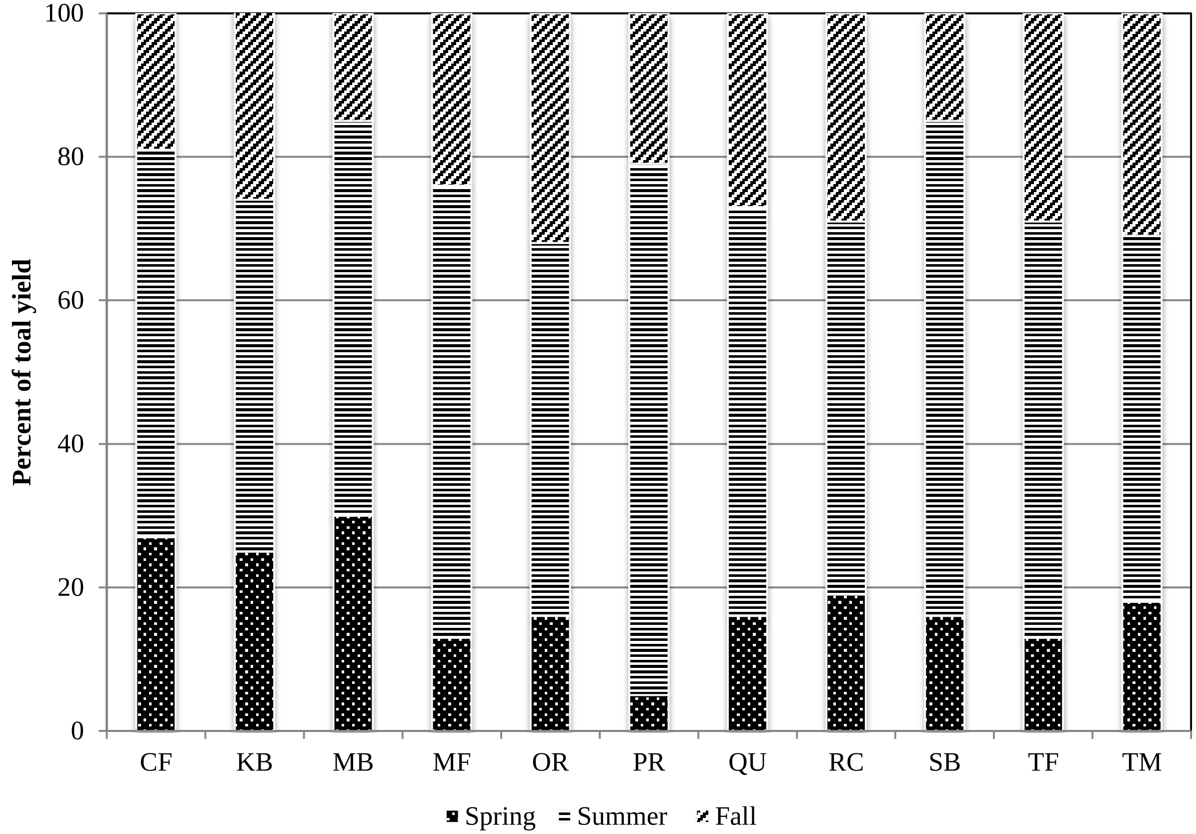
[a-e] Mean separations are within columns and years. Values with the same letter are not significantly different ($P \leq 0.05$).

Figure 1.1. Percent of total yield throughout the grazing season for cool-season grasses under horse grazing in 2010.



CF, creeping foxtail; KB, Kentucky bluegrass; MB, meadow bromegrass; MF, meadow fescue; OR, orchardgrass; PR, perennial ryegrass; QU, quackgrass; RC, reed canarygrass; SB, smooth bromegrass; TF, tall fescue; TM, timothy.

Figure 1.2. Percent of total yield throughout the grazing season for cool-season grasses under horse grazing in 2011.



CF, creeping foxtail; KB, Kentucky bluegrass; MB, meadow bromegrass; MF, meadow fescue; OR, orchardgrass; PR, perennial ryegrass; QU, quackgrass; RC, reed canarygrass; SB, smooth bromegrass; TF, tall fescue; TM, timothy.

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Chapter 3

Forage Quality and Preference of Cool-Season Grasses Under Horse Grazing

E.M. Allen[1], K.L. Martinson[1], C.C. Sheaffer[2]

[1]Department of Animal Science, University of Minnesota, St. Paul, MN
[2]Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN

Chapter Summary

Most forage cultivars are not evaluated under livestock grazing. The objectives were to evaluate preference and forage quality of cool-season grasses under horse grazing. Research was conducted in 2010 and 2011 in which horses grazed 'Barolex' tall fescue (*Schedonorus phoenix* Scop.), 'Hidden Valley' meadow fescue (*Schedonorus pratensis* Huds.), 'Everett' quackgrass (*Elymus repens* L.), 'Agassiz' smooth bromegrass (*Bromus inermis* Leyss.), 'Fleet' and 'Paddock' meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.), 'Marathon' reed canarygrass (*Phalaris arundinacea* L.), 'Survivor' perennial ryegrass (*Lolium perenne* L.), 'Winneton' timothy (*Phleum pretense* L.), 'Ginger' Kentucky bluegrass (*Poa pratensis* L.), 'Garrison' creeping foxtail (*Alopecurus arundinaceus* Pior.), and 'Baridana' orchardgrass (*Dactylis glomerata* L.). Samples were hand-harvested before grazing and were analyzed for crude protein (CP), neutral detergent fiber (NDF), and neutral detergent fiber digestibility (NDFD). To assess preference, plots were visually evaluated post-grazing for removal on a scale of 0 to 100%. Kentucky bluegrass, timothy, and meadow fescue were the most preferred grasses while meadow bromegrass, creeping foxtail, reed canarygrass, and orchardgrass were less preferred ($P \leq 0.05$). Perennial ryegrass, quackgrass, reed canarygrass, and smooth bromegrass had high concentrations of CP, while Kentucky bluegrass, orchardgrass, creeping foxtail, and timothy were lower in CP ($P \leq 0.05$). Quackgrass had lower NDF values compared to higher amounts found in creeping foxtail and smooth bromegrass ($P \leq 0.05$). Perennial ryegrass and meadow fescue were higher in NDFD, while creeping foxtail and Kentucky bluegrass were lower ($P \leq 0.05$). To maximize forage use, grasses with similar preferences should be planted in horse pastures.

Key Words: horse, cool-season grass, preference, forage quality

Introduction

Cool-season perennial grasses are the foundation of productive horse pastures in the North Central U.S. Grass forage quality factors such as nutritive value and palatability affects their utilization. Differences in palatability, or selection when a choice is given (Marten et al., 1987), affects not only animal utilization of a grass, but ultimately grass persistence if pastures are continuously grazed. Horses are known to be selective grazers, especially compared to other livestock, and will demonstrate a preference for certain grasses over others (Archer, 1973a,b). In previous research, orchardgrass (*Dactylis glomerata* L.) (Olson et al., 2009, 2011; Wilson and Hoormann, 2004), creeping red fescue (*Festuca rubra* L.) (Archer, 1978) and smooth bromegrass (*Bromus inermis* Leyss.) (Olson et al., 2009) were preferred by grazing horses, while meadow foxtail (*Alopecurus pratensis* L.) was less preferred (Archer, 1978). Preference of Kentucky bluegrass (*Poa pratensis*), perennial ryegrass (*Lolium perenne* L.), tall fescue (*Schedonorus phoenix* Scop.), festulolium (*Festulolium braunii* K. Richt.), and timothy (*Phleum pretense* L.) have been inconsistent, and have depended on cultivar and location when grazed by horses (Olson et al., 2009, 2011; Wilson and Hoormann, 2004; Archer 1980 and 1978). However, little current information on horse preference of cool-season grasses in the Midwestern U.S exists.

Plant morphology and chemical compositon are important factors affecting preference (Marten, 1978). McAnn and Hoveland (1991) found that forage maturity in cool-seasaon grasses, such as annual ryegrass (*Lolium multiflorum* L.) and other species, was an important factor in determining horse preference, and that horses selected less mature, leafier grasses. In addition, physical factors such as pubescence and leaf coarseness affect livestock preference (Vallentine, 2001). Byrd and Longland (2006) reported a positive relationship between horse preference and soluble carbohydrates, while others have reported a negative relationship between fiber concentrations and ruminant preference of forages, i.e., Kentucky bluegrass and orchardgrass (Fontenot and Blaser, 1965).

Forage nutritive value of cool-season grasses varies among species, and is affected by many factors, including maturity and environmental conditions. While some grasses, like perennial ryegrass, have been shown to be more digestible compared to others (Terry and Tilley, 1964). However, most cool-season grasses have similar fiber and carbohydrate fractions when harvested at similar stages of maturity. Forage quality decreases with maturity due to decreased leafiness and increases in the more fibrous stem fractions (Terry and Tilley, 1964). For example, crude protein (CP) concentrations of timothy (Cherney et al., 1993) and perennial ryegrass (Hoffman et al., 1993) decreased from 178 to 122 g/kg from the vegetative to boot stage, respectively. Other cool-season grasses, including orchardgrass, Kentucky bluegrass, and reed canarygrass had CP concentration that ranged from 109 to 115 g/kg (Hockensmith, 1997), while Hoffman et al. (1993) reported smooth bromegrass CP concentrations were higher, and ranged from 122 to 195 g/kg. Previous research determined that neutral detergent fiber (NDF) concentrations of most cool season grasses were between 500 to 600 g/kg (Marten et al., 1987; Sanderson and Wedin, 1989; Cherney et al., 1993; Hoffman et al., 1993). However, some have found higher NDF concentrations (> 600 g/kg) in orchardgrass (Collins and Casler, 1990; Hockensmith, 1991; Cherney et al., 1993), Kentucky bluegrass and reed canarygrass (Hockensmith, 1991). Ulyatt (1981) found that over the growing season, NDF digestibility concentrations for most cool-season grasses average 700 g/kg.

Although considerable research has shown differences in perennial grass forage quality when harvested at more mature stages, there is a need to evaluate forage quality of cool-season grasses over the course of a grazing season, when grasses are frequently grazed by horses and kept in the vegetative stage. Therefore, the objectives of this research were to evaluate grazing preferences and forage quality of cool-season grasses under horse grazing.

Materials and Methods

Research was conducted in St. Paul, MN in 2010 and 2011 using stands of cool-season grasses established in August 2009. The experimental design was a randomized complete block with four replicates. Each replicate contained twelve cool-season grass monocultures, including ‘Barolex’ tall fescue (*Schedonorus phoenix* Scop.), ‘Hidden Valley’ meadow fescue (*Schedonorus pratensis* Huds.), ‘Everett’ quackgrass (*Elymus repens* L.), ‘Agassiz’ smooth bromegrass (*Bromus inermis* Leyss.), ‘Fleet’ and ‘Paddock’ meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.), ‘Marathon’ reed canarygrass (*Phalaris arundinacea* L.), 'Survivor' perennial ryegrass (*Lolium perenne* L.), 'Winneton' timothy (*Phleum pretense* L.), 'Ginger' Kentucky bluegrass (*Poa pratensis* L.), 'Garrison' creeping foxtail (*Alopecurus arundinaceus* Pior.), and 'Baridana' orchardgrass (*Dactylis glomerata* L.). Individual plots were 3 x 6 m. Soil type was a Waukegan silt loam (fine-silty over skeletal, mixed, superactive, mesic Typic Hapludoll). Soil pH was 6.6, P was 18 ppm, and K was 85 ppm and grasses were fertilized with 56 kg N per ha in early April and in mid-June of each year.

Forage harvesting and grazing were initiated when most grasses reached 20 cm, except Kentucky bluegrass which averaged 10 cm, on 18 May, 16 June, 19 July, 16 August, 14 September , and 11 October in 2010 and 17 May, 14 June, 12 July, 16 August, and 13 September in 2011. Due to lack of rainfall and subsequent re-growth, grasses were not harvested or grazed in October 2011. Forage samples retained for quality analysis were hand-harvested to a 9 cm height from duplicate 0.25 m square areas between 0800 and 1200 h. Samples were weighed and dried for 24 hours in a 60°C dryer to determine DM. After drying, flakes were ground through a 6 mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) followed by a 1 mm screen in a Cyclotec (Foss, Eden Prairie, MN). Samples were mixed thoroughly and subsamples were submitted for nutrient analysis. Crude protein, NDF, and *in vitro* true digestibility (IVTD) were estimated by NIRS, using NIRS predictions equations developed for pasture grasses in Minnesota. Dried and ground forage samples were scanned (model DA 7200, Perten) and prediction equations for CP, NDF, and IVTD were developed from 87, 86, and 73 samples, respectively, collected in 2010 and 2011. The standard error of cross validation was 0.98, 2.1 and 2.64, respectively, for CP, NDF, and IVTD, while the R^2 was 0.98, 0.91, and 0.91, respectively. Crude protein (N x 6.25) of selected samples was determined by first determining N concentration using N combustion (AOAC 990.03). Neutral detergent fiber and IVTD were determined using methods of Goering and Van Soest (1970). Neutral detergent fiber digestibility (NDFD) was calculated from NDF and IVTD using equations developed by Hoffman et al. (2001). In 2010 only, subsamples were submitted for nutrient analysis at a commercial laboratory (Equi-Analytical, Ithaca, NY) for analysis of non-structural carbohydrates (NSC), which was estimated by adding WSC plus starch (Byrd and Longland, 2006).

Four adult quarter horses (averaged 538 kg BW and 21 years in 2010, and 477 kg BW and 24 years in 2011) were used for grazing. Before grazing, horses were acclimated for five days in an adjacent pasture of mixed grass. Following the acclimation period, horses were grazed on the first two replicates for eight hours on day one, followed by the final two replications for eight hours the following day, resulting in two consecutive days of grazing each month. The total size of each grazed area (containing two replicates) was 21 by 30.5 m. Immediately after grazing, plots were visually assessed for removal on a scale of 0 (no grazing activity) to 100 (100% of the existing vegetation grazed) to determine horse preference. Horses were given *ad libitum* access to water, housed in a dry lot, and fed a grass-alfalfa mix hay when not grazing. After grazing, manure was removed, plots were mowed to 9 cm and allowed to regrow. All experimental procedures were conducted according to those approved by the University of Minnesota Committee on Animal Use and Care.

Data were analyzed using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC; version 9.2). Plots were the experimental unit and statistical significance was set at $P \leq 0.05$. Means are the least square means of the Mixed procedure. Grass species and months were designated as fixed effects. No difference between ‘Fleet’ and ‘Paddock’ meadow bromegrass were found, thus the data was combined and will be referred to as meadow bromegrass. Although grazing occurred at monthly intervals, data was analyzed represented as climatological seasons, including spring (May), summer (July), and fall (September). Other months were not included in the data analysis. Preference and forage quality results for each year were different ($P \leq 0.5$) and are presented separately. To assess the relationship between preference and quality, a linear mixed model using post-grazing removal was fit with forage quality components (CP, NDF, NDFD, NSC) as predictors with additive random slopes for each 8 hour grazing session with grass species as random intercepts.

Results and Discussion

Maturity

Maturities of grasses throughout the grazing seasons in 2010 and 2011 are detailed in Allen et al., (2012). Grazing was initiated when all grasses, except Kentucky

Bluegrass averaged 20 cm tall, therefore most grasses were grazed at the vegetative stage. However, five grasses did have elongated culms during the spring and summer of each year, including creeping foxtail, meadow bromegrass, perennial ryegrass, reed canarygrass and timothy. Creeping foxtail in the spring and perennial ryegrass in the summer did reach reproductive stages. Kentucky bluegrass, meadow fescue, orchardgrass, and tall fescue had no culm elongation during the summer and fall.

Preferences

Throughout the grazing season, horses showed distinct preferences among the grasses ($P \leq 0.001$; Table 1). The most preferred ($P \leq 0.0001$) grasses were Kentucky bluegrass, meadow fescue, and timothy, with post-grazing forage removals ranging from 40 to 96%, however, most removals were less than 60%. Kentucky bluegrass and meadow fescue were more consistently preferred, while timothy preference was greater in the summer and fall and lower in the spring. Previous researchers found that horse preference for these grasses was variable and generally described as moderate (Archer, 1973a; Olson et al., 2009, 2011). However, Casler and Van Santen (2001) found that cattle preferred meadow fescue over other cool-season grasses.

Moderately preferred grasses included quackgrass, tall fescue, perennial ryegrass and smooth bromegrass, with post-grazing removals ranging from 45 to 95%. Archer (1978 and 1980) and Olson et al. (2011) also concluded that perennial ryegrass and tall fescue were moderately preferred by horses, and Casler and Van Santen (2001) observed the same trend for tall fescue in cattle. Similarly, Marten et al., (1987) observed that quackgrass palatability was moderate when grazed by sheep. Contrary to Olson et al., (2009) who concluded smooth bromegrass was highly preferred by horses, smooth bromegrass preference was determined to be moderate in the current study.

Meadow bromegrass, creeping foxtail, reed canarygrass, and orchardgrass were the least preferred grasses, with post-grazing removals ranging from 28 to 69%. This contradicts previous researchers (Olson et al., 2009; Wilson and Hoormann, 2004), who determined orchardgrass was highly preferred by horses. Other species of forage foxtails have also been found to be less preferred by horses (Archer, 1978).

Differences in palatability are observed only when a choice is given. We hypothesize that differences in cool-season grass varieties, weather conditions, geographic location, and species offered likely contributed to the differences in horse preference between past research and the current study. Selection of pasture mixes that include grasses with similar horse preferences should enhance uniform grazing, thus maximize forage use and minimize pasture maintenance and associated expenses.

Forage Quality

Crude protein concentrations differed among grasses throughout the grazing season in 2010 and 2011 (Tables 2 and 3). During both years, perennial ryegrass, reed canarygrass, smooth bromegrass, and quackgrass had the greatest CP concentration ranging from 202 to 253 g/kg and 200 to 274 g/kg, respectively ($P \leq 0.0604$). Crude protein concentrations of these grasses were higher than previous reports (Waite et al., 1964; Cherney et al., 1993; Hoffman et al., 1993; and Hockensmith, 1997). Grasses in the current study were grazed monthly and were generally vegetative. Our results concur with other reports that found higher forage CP concentrations in grasses when vegetative or at stem elongation compared to reproductive stages (Hoffman et al., 1993 and 1993; Cherney et al., 1993), possibly explaining the differences between the current study and previously published cool-season grass CP amounts.

Grasses that were lower ($P \leq 0.0604$) in CP for both years included Kentucky bluegrass, orchardgrass, creeping foxtail, and timothy. Results for timothy were comparable to previous research (Cherney et al., 1993 and Hoffman et al., 1993) while CP concentration of Kentucky bluegrass and orchardgrass observed in the current study were higher than previously reported (Hockensmith, 1997 and Hoffman et al., 1993). Waldie et al. (1983) found that CP concentrations were similar between timothy and creeping foxtail, which was similar to results observed in the current study, except for spring 2011 when creeping foxtail had greater amount of CP compared to timothy. However, even the lowest concentration of CP observed in the current study would have provided more than twice the amount of CP needed by a 500 kg mature horse in moderate exercise (at intake equal to 2.25% BW) (NRC, 2007).

Concentrations of NDF varied between the years, with few grasses having consistently high or low amounts of NDF ($P \leq 0.0001$). Quackgrass tended to have lower NDF values that ranged from 362 to 566 g/kg. Although there is a greater range in quackgrass NDF values observed in the current study, the NDF values are comparable to previous findings (Marten et al., 1987 and Hoffman et al., 1993). Creeping foxtail and smooth bromegrass tended to have the highest amounts of NDF, and ranged from 477 to 609 g/kg. Neutral detergent fiber values for smooth bromegrass are similar (Hoffman et al., 1993) to slightly lower (Hockensmith, 1997) than those previously reported.

Other grasses varied widely in NDF concentrations between the years. Meadow bromegrass and Kentucky bluegrass were among the grasses with higher NDF values in 2010, but had lower values in 2011. Conversely, perennial ryegrass and meadow fescue were among the grasses with lower NDF values in 2010, but had higher NDF values in 2011. Neutral detergent fiber values for the remaining cool-season grass were similar, or slightly lower, than previous research (Sanderson and Wedin, 1989; Cherney et al., 1993; Collins and Casler, 1990; Hoffman et al., 1993; Hockensmith, 1997). However, grasses in the current study were managed to remain in a vegetative growth stage, which likely accounts for the lower NDF values.

Neutral detergent fiber digestibility differed among grasses ($P \leq 0.0001$; Tables 2 and 3). Perennial ryegrass and meadow fescue consistently had higher NDFD ($P \leq 0.001$) values than other grasses, and ranged from 901 to 714 g/kg and 588 to 701 g/kg, respectively. Other grasses that tended to have greater NDFD values included timothy, tall fescue and reed canarygrass. Others have also determined these grasses to be highly digestible (Brink et al., 2010 and Brink and Soder, 2011). Brink et al. (2010) and Brink and Soder (2011) have also observed similar NDFD values for meadow fescue, reed canarygrass and tall fescue.

Kentucky bluegrass, smooth bromegrass, quackgrass, reed canarygrass, and creeping foxtail had the lowest NDFD values ($P \leq 0.0001$; Tables 2 and 3), with values ranging from 458 to 750 g/kg. The lower NDFD values observed in Kentucky bluegrass, smooth bromegrass, and creeping foxtail correspond to the higher NDF values observed for these grasses. Most other grasses had moderate levels of NDFD that ranged from 555 to 770 g/kg, with few differences in NDFD observed during the summer and fall when grasses were more likely to be in the vegetative growth stage. These results are similar to Ulyatt (1981) who found digestibility concentrations for most cool-season grasses average 700 g/kg. Robins and Jensen (2011) observed higher concentrations of NDFD in creeping foxtail than in the current study.

Nonstructural carbohydrates concentrations were only evaluated in 2010. Concentrations of NSC were not different among grasses, except during the summer, and ranged from 63 to 169 g/kg throughout the year. During the summer, timothy, Kentucky bluegrass, meadow fescue, and perennial ryegrass had higher amounts of NSC, and ranged from 104 to 169 g/kg, while meadow bromegrass, orchardgrass, and reed canarygrass were lower, and ranged from 63 to 95 g/kg NSC ($P \leq 0.0001$). Pelletier et al. (2010) determined that TNSC concentrations, similar to NSC, of several cool-season grasses ranged from 44 to 97 g/kg, which were lower than the NSC range observed in the current study, however, similar trends were observed. Pelletier et al. (2010) also found meadow bromegrass tended to be lower in TNC, while timothy tended to have higher amounts of carbohydrates. The differences in carbohydrate amounts between the two studies can likely be explained by weather and harvest conditions. Cool-season grasses will continue to accumulate carbohydrates in the presence of sunlight, in excess of basic plant metabolism needs, leading to wide ranges in carbohydrate values (Watts and Chatterton, 2004).

Horses are known to be selective grazers, however, little is known about what drives horse preference in a pasture system. In the current study, NSC ($P = 0.005$) was positively correlated to horse preference, while there was a trend for NDFD ($P = 0.09$) to be positively correlated, and NDF ($P = 0.09$) to be negatively correlated to horse preference in 2010. Crude protein ($P = 0.83$) and maturity ($P = 0.64$) were not correlated to horse preference in 2010. In 2011, no factors (maturity, CP, NDF and NDFD) were correlated to horse preference ($P \geq 0.62$). The results observed in 2010 were similar to others who have found a positive relationship between preference and soluble carbohydrates (Reid et al., 1967 and Byrd and Longland, 2006), and a negative relationship between preference and fiber concentrations (Fontenot and Blaser, 1965). Contrary to past research (McAnn and Hoveland, 1991 and Hunt, 1994), no correlation was observed between forage maturity and preference. The lack of correlation between forage quality and horse preferences in 2011 highlights the fact that horse preference is a complicated issue that is likely impacted by several confounding factors.

Conclusions

Understanding horse grazing preferences is a complicated issue. During the first year of grazing, NSC and NDFD were positively correlated, and NDF was negatively correlated to horse preference, however, the same trends were not observed during the second year of grazing. Kentucky bluegrass, timothy, and meadow fescue were the most preferred grasses. Kentucky bluegrass and timothy tended to have lower CP concentration and Kentucky bluegrass had lower NDFD values. Meadow fescue tended to have higher NDFD values throughout the grazing season.

Quackgrass, tall fescue, perennial ryegrass, and smooth bromegrass were moderately preferred by horses. Quackgrass tended to have higher amounts of CP and NDF, and lower levels of NDFD, while perennial ryegrass had higher CP and NDFD concentrations throughout the grazing season. Smooth bromegrass also recorded high concentrations of CP, lower amounts of NDF, but resulted in lower NDFD values. Reed canarygrass tended to have high CP concentration, while meadow fescue tended to have high NDFD values.

Meadow bromegrass, creeping foxtail, reed canarygrass, and orchardgrass were less preferred by horses. Creeping foxtail was the lowest quality cool-season grass evaluated, with low CP and NDFD, and high NDF values. Crude protein of orchardgrass was also lower, compared to other grasses.

To maximize forage use, grasses with similar preferences should be planted in horse pastures. A mixture that results in uniform grazing should maximize forage use and minimize pasture maintenance and associated expenses. However, information on forage persistence and yield should also be taken into consideration when developing cool-season grass mixtures for horse pastures.

Table 2.1. Preferences for cool-season grasses during the 2010 and 2011 grazing season.

	2010			2011		
Species	**Spring**[†]	**Summer**	**Fall**	**Spring**	**Summer**	**Fall**
	% removal[‡]					
Creeping Foxtail	69^{abcd}	29^{de}	35^{d}	39^{d}	38^{c}	-----[§]
Kentucky Bluegrass	95^{a}	91^{a}	85^{ab}	86^{ab}	60^{bc}	48^{b}
Meadow Bromegrass	33^{e}	28^{e}	29^{d}	43^{cd}	42^{c}	53^{ab}
Meadow Fescue	40^{de}	61^{b}	88^{a}	71^{abc}	75^{ab}	65^{ab}
Orchardgrass	45^{cde}	33^{cde}	69^{abc}	46^{cd}	45^{c}	45^{b}
Perennial Ryegrass	54^{bcde}	46^{bcd}	70^{abc}	95^{a}	75^{ab}	45^{b}
Quackgrass	74^{abc}	53^{b}	75^{abc}	45^{cd}	54^{bc}	63^{ab}
Reed Canarygrass	45^{cde}	44^{bcde}	55^{cd}	41^{cd}	42^{c}	71^{ab}
Smooth Bromegrass	53^{bcde}	48^{bc}	74^{abc}	64^{abcd}	60^{bc}	69^{ab}
Tall Fescue	80^{ab}	46^{bcd}	56^{bcd}	63^{bcd}	61^{bc}	50^{ab}
Timothy	49^{cde}	89^{a}	96^{a}	69^{abcd}	93^{a}	85^{a}
SEM	*7*	*4*	*6*	*7*	*6*	*7*
P-value	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*0.0027*

[a-e] Mean separations are within columns and years. Values with the same letter are not significantly different ($P \leq 0.05$).
[†] Spring values refer to data collected in May, Summer from July, and Fall from September.
[‡] Preference assessed as percent removal (horse grazing) ranging from 0 (no evidence of grazing) to 100 (100% of plants grazed to a height of 8 cm).
[§] Creeping foxtail stand (< 50% ground cover) was too limited to assess preference.

Table 2.2. Crude protein, neutral detergent fiber, and neutral detergent fiber digestibility, for cool-season grasses for the 2010 grazing season.

Species	**Spring[†]**			**Summer**			**Fall**		
	CP[‡]	**NDF**	**NDFD**	**CP**	**NDF**	**NDFD**	**CP**	**NDF**	**NDFD**
	--g/kg--								
Creeping Foxtail	193^{c}	465^{bcd}	686^{de}	186^{bcd}	609^{a}	469^{d}	218^{ab}	493	600
Kentucky Bluegrass	159^{e}	538^{a}	666^{e}	184^{cd}	601^{a}	543^{abc}	190^{ab}	506	599
Meadow Bromegrass	224^{ab}	448^{cde}	701^{cde}	173^{d}	594^{ab}	475^{cd}	216^{ab}	463	592
Meadow Fescue	187^{cd}	446^{de}	775^{b}	175^{d}	526^{e}	588^{a}	199^{ab}	439	679
Orchardgrass	183^{cd}	475^{bc}	710^{cde}	167^{d}	589^{abc}	491^{bcd}	179^{b}	473	606
Perennial Ryegrass	202^{bc}	396^{g}	901^{a}	221^{a}	547^{cde}	527^{abcd}	253^{a}	476	668
Quackgrass	235^{a}	416^{fg}	749^{bc}	207^{abc}	566^{abcde}	458^{d}	208^{ab}	455	609
Reed Canarygrass	220^{ab}	456^{bcde}	725^{bcde}	212^{ab}	544^{cde}	556^{ab}	210^{ab}	473	610
Smooth Bromegrass	233^{a}	435^{ef}	741^{bcd}	227^{a}	577^{abcd}	458^{d}	226^{ab}	450	597
Tall Fescue	192^{c}	459^{bcde}	728^{bcd}	193^{bcd}	538^{de}	553^{ab}	206^{ab}	467	634
Timothy	166^{de}	480^{b}	697^{cde}	182^{cd}	549^{bcde}	564^{a}	176^{b}	479	652
SEM	*6*	*7*	*15*	*8*	*15*	*21*	*17*	*16*	*24*
P-value	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*0.0604*	*0.1019*	*0.0607*

[a-g] Mean separations are within columns and seasons. Values with the same letter are not significantly different ($P \leq 0.05$).

[†] Spring values refer to data collected in May, Summer from July, and Fall from September.

[‡] CP, crude protein; NDF, neutral detergent fiber; NDFD, neutral detergent fiber digestibility.

Table 2.3. Crude protein, neutral detergent fiber, and neutral detergent fiber digestibility concentrations for cool-season grasses for the 2011 grazing season.

Species	**Spring**[†]			**Summer**			**Fall**		
	CP[‡]	**NDF**	**NDFD**	**CP**	**NDF**	**NDFD**	**CP**	**NDF**	**NDFD**
	-----------------	-----------------	-----------------	------ **g/kg** ------	-----------------	-----------------	-----------------	-----------------	-----------------
Creeping Foxtail	190[cd]	448[bc]	642[ef]	221[d]	477[bc]	591[de]	215[ab]	479[ab]	667[bc]
Kentucky Bluegrass	182[d]	406[e]	638[f]	215[d]	461[bc]	599[cde]	192[b]	454[b]	653[bc]
Meadow Bromegrass	213[abc]	410[e]	686[def]	229[bcd]	482[bc]	603[bcde]	230[ab]	480[ab]	689[abc]
Meadow Fescue	202[bcd]	423[cde]	767[b]	238[bcd]	481[bc]	682[ab]	208[ab]	523[ab]	758[a]
Orchardgrass	201[bcd]	422[de]	704[cd]	215[d]	485[bc]	597[de]	194[b]	467[ab]	648[bc]
Perennial Ryegrass	236[a]	456[b]	854[a]	256[ab]	486[bc]	714[a]	236[ab]	484[ab]	768[a]
Quackgrass	220[ab]	362[f]	722[bcd]	252[abc]	434[c]	558[e]	232[ab]	452[b]	653[bc]
Reed Canarygrass	200[bcd]	439[bcd]	675[def]	241[bcd]	473[bc]	621[bcde]	242[a]	503[ab]	697[abc]
Smooth Bromegrass	215[abc]	485[a]	691[de]	274[a]	560[a]	574[e]	206[ab]	538[a]	636[c]
Tall Fescue	211[abc]	459[b]	678[def]	226[cd]	504[ab]	654[abcd]	200[ab]	514[ab]	715[abc]
Timothy	190[cd]	417[de]	741[bc]	232[bcd]	488[bc]	677[abc]	193[b]	495[ab]	718[ab]
SEM	*7*	*7*	*10*	*8*	*13*	*17*	*11*	*17*	*18*
P-value	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*<.0001*	*0.0027*	*0.0061*	*<.0001*

[a-f] Mean separations are within columns and seasons. Values with the same letter are not significantly different ($P \leq 0.05$).

[†] Spring values refer to data collected in May, Summer from July, and Fall from September.

[‡] CP, crude protein; NDF, neutral detergent fiber; NDFD, neutral detergent fiber digestibility.

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