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Three Overlooked Issues: Water Quality, Forage Quality, and Forage Blends Impacting the Feed Efficiency of Dairy Cows

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THREE OVERLOOKED ISSUES: WATER QUALITY, FORAGE QUALITY, AND FORAGE BLENDS IMPACTING THE FEED EFFICIENCY OF DAIRY COWS

BY

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THREE OVERLOOKED ISSUES: WATER QUALITY, FORAGE QUALITY, AND FORAGE BLENDS IMPACTING THE FEED EFFICIENCY OF DAIRY COWS

This dissertation is approved as a creditable and independent investigation by a candidate for the Doctor of Philosophy degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this dissertation does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Head, Dairy Science Department

Dean, Graduate School Date

This dissertation is dedicated to my beloved parents, Shashidhar Acharya and Bhagirathi Acharya, wife, Roshani Kandel and daughter, Ishani Acharya

यो शोधपत्र मेरा पूज्यनीय पिता शशिधर आचार्य, माता भागीरथी आचार्य, जीवनसंगिनी रोशनी कँडेल तथा प्यारी सुपुत्री ईशानी आचार्यमा समर्पण गर्दछु ।

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ABBREVIATIONS

ADF	Acid detergent fiber
ADG	Average daily gain
ADICP	Acid detergent insoluble crude protein
AH	Alfalfa hay
AMTS	Agricultural modelling and training systems
ANOVA	Analysis of variance
AOAC	Association of official agricultural chemist
APHIS	Animal and plant health inspections service
BCS	Body condition score
BM	Blood meal
BMR	Brown mid rib
BUN	Blood urea nitrogen
Ca	Calcium
Cd	Cadmium
CF	Crude fiber
CFU	Colony forming unit
CGM	Corn gluten meal
CH_4	Methane
Cl	Chlorine
CO_2	Carbon di oxide
CP	Crude protein
Cr	Chromium
Cu EDTA	Copper ethylenediaminetetraacetic acid
d	day(s)

DCAD	Dietary cation anion differences
DG	Distillers grain
dH_2O	Distilled water
DIM	Days in milk
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake
DMY	Dry matter yield
dNDF	Digestible neutral detergent fiber
DRTF	Dairy research and training facility
EC	Electrical conductivity
ECM	Energy corrected milk
EE	Ether extract
ELSD	Evaporative light scattering detector
F	Fluorine
FCM	Fat corrected milk
Fe	Iron
g	gram
GC	ground corn
GFB	Gas fermentation bottle
GM	Grain mixed
GMO	Genetically modified organism
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulfuric acid
ha	Hectare

Hg	Mercury
HPLC	High performance liquid chromatography
isSD7	7 hours starch digestibility
IVDMD	In vitro dry matter digestibility
IVTD	In vitro true digestibility
K	Potash
Kd	Rate of digestion or degradation
L	Liter
LER	Land equivalent ratio
MC	Masters choice
Mg	Magnesium
MG	Mastergraze
mg/dL	Milligram per deciliter
mg/L	Milligram per liter
$MgSO_4$	Magnesium sulfate
mL	Milliliter
mM/L	Millimole per liter
mmol/L	Millimole per liter
MUN	Milk urea nitrogen
N	Nitrogen
Na	Sodium
NDF	Neutral detergent fiber
NDFD	Neutral detergent fiber digestibility
NDFD30	30 hours neutral detergent fiber digestibility
NDICP	Neutral detergent insoluble crude protein

NE	Net energy
NEFA	Non-esterified fatty acids
NE_G	Net energy for growth
NE_L	Net energy for lactation
NE_M	Net energy for maintenance
NFC	Non fiber carbohydrates
NRC	National research council
NSC	Non-structural carbohydrates
OM	Organic matter
P	Phosphorus
Pb	Lead
PC	Personal computer
PEM	Polioencephalomalacia
pH	Hydrogen ion concentration
ppm	Parts per million
psi	Pounds per square inch
PSPS	Penn state particle separator
R^2	Coefficient of determination
rBST	Recombinant bovine somatotropin
RCBD	Randomized complete block design
RR	Roundup ready
SAS	Statistical analysis software
SBM	Soybean meal
SBP	Soybest pearl
SCC	Somatic cell counts

SE	Standard error
SEM	Standard error of means
SNF	Solid not fat
SO_4	Sulfate
SP	Soluble protein
TDN	Total digestible nutrients
TDS	Total dissolved solids
TMR	Total mixed ration
T	Metric ton
TS	Total solids
TSS	Total soluble salts
uNDF	Undigestible neutral detergent fiber
EPA	Environmental protection agency
USDA	United States department of agriculture
UUN	Urinary urea nitrogen
UV	Ultra violet
vol	Volume
WCS	Whole cotton seeds
wk	Week(s)
wt	Weight
Zn	Zinc

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ABSTRACT

THREE OVERLOOKED ISSUES: WATER QUALITY, FORAGE QUALITY, AND FORAGE BLENDS IMPACTING THE FEED EFFICIENCY OF DAIRY COWS

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The overall objectives of the six studies were to increase the feed efficiency in lactating dairy cows. The first study evaluated the efficacy of different water sources and treatment systems on ruminal parameters using an in vitro gas production system. Outcomes of the study suggested that the source and nutrient quality of water can affect rate of ruminal fermentation. Thus, use of real farm water being offered to the cow to conduct in vitro gas production measurements may accurately predict the ruminal fermentation, digestibility and total gas production. The second study evaluated two recently developed leafy-floury corn silage hybrids against conventional starchy corn silage hybrid on performance of early lactating dairy cows. The results showed that all three corn silage hybrids are similar in terms of DMI, milk yield, milk components and 3% fat corrected milk FE. Starchy corn silage hybrid was lower in CP, higher in starch, lower in sugar content, lower in starch digestibility and lower in fiber digestibility compared to both leafy-floury corn silage hybrids. This study demonstrates that a lower starch, higher digestible fiber corn silage diet can support similar milk production compared to a higher starch, lower digestible fiber diet. The third study evaluated intercropping of Vining soybean and BMR grazing corn with different seeding ratios on forage yield, nutrients composition and digestibility. The results showed that

monocropping of Vining soybean produced lower DM yield, lower DDM yield, lower NFC yield and lower milk yield (T/ha) compared to intercropping of Vining soybean and BMR grazing corn with monocropping of BMR grazing corn being intermediate. The optimal seeding ratio of Vining soybean to BMR grazing corn is between 67:33 and 50:50 based on yield of DDM and Milk (T/ha). The fourth study evaluated late season row cropping of mixed seeds of corn and soybean with different seeding ratios on forage yield, nutrient yields and digestibility. The result showed that the combinations and seeding ratios of corn and soybean affect the forage and nutrient yields. The greatest yield of nutrients occurred with BMR grazing corn and Big Buck 6 soybean combination at 65:35 seeding ratio. A minimum of 90 d is required to complete the ensiling process of forage before feeding to the cow. The fifth study evaluated the effect of intercropping of MC 5300 corn with Viking 2265 soybean or Vining soybean at different seeding ratios on biomass and nutrient yields under organic condition. The results showed that seeding ratio of MC 5300 corn and Vining soybean or Viking 2265 at 67:33 produced higher fresh biomass yield and dry matter yield. Land equivalent ratio was greater for MC 5300 corn and Viking 2265 soybean combination at 67:33 or 50:50 seeding ratios. The sixth study evaluated the effect of row cropping of mixed seeds of corn and soybean with different seeding ratios on forage and nutrient yields grown under organic condition. The main effect of corn on fresh, DM, DDM, CP, NDF, NFC and starch yield was higher for MC 5300 corn compare to BMR grazing corn, but the main effect of soybean on Viking 2265 or Vining soybean was similar. Corn and soybean seeding ratio at 65:35 produced more forage and nutrient yields compare to 55:45, 45:55, or 35:65 seeding ratios.

INTRODUCTION

Water is a vital nutrient and plays a pivotal role in milk production (Mann et al., 2013), but water is often a forgotten and overlooked nutrient in livestock production. However, water sources and quality are becoming greater concerns for dairy farmers as they continue to grow their operation, thereby creating additional stress on water resources. Drawing greater water volumes, weather patterns, fertilizer application to crops, accidental insecticide spills, pesticides and petroleum products, bacterial contamination, high mineral concentrations, high nitrates, and toxic blue green algae can be factors that might affect water quality within a specific water source. Water quality is not well understood as to the impact on livestock production and performance. In addition, little information exists in the scientific literature on water quality and composition influencing the nutritional performance of lactating dairy cows. Water quality and nutrient contents can have an impact on the feed intake, lactational performance, reproduction, as well as, the occurrence of metabolic problems that might occur at calving (Schauff et al., 2000). Having an excellent working knowledge about providing this most important essential nutrient is crucial for optimum performance of dairy cattle and the financial success of dairy businesses (Beede, 2006). The current in vitro gas fermentation system is using distilled water to determine the rate and extent of nutrient digestibility rates of feeds and forages. Since, dairy cows are offered dairy operation water sources (not distilled water), the results might be different on the farm than what is observed in the laboratory. Distilled water is usually free of salts, nitrates, minerals and bacteria and cannot necessarily represent farm water sources that may have a vastly different impact on fermentation, gas production and nutrient digestibility.

Feed is the single highest cost of milk production which accounts for approximately 50 to 70% of the total cost involved in milk production and forage typically make up the greatest percentage of the diets (Stone, 2010). Forages are the foundation upon which nutritionally sound, economical and rumen healthy rations are built. The quality and quantity of forages fed to the dairy herd is directly related to milk production, purchased feed costs, whole farm nutrient balance and profitability. Forages are the key to healthy and productive cows and successful dairying. Forage quality is defined in several ways, but is often poorly understood. Though very important, forage quality often gets far less attention than it deserves. The extent to which forage has the potential to produce a desired animal response is called forage quality. The better the forage quality, the more of it cows eat, the better cows perform, and the less need to supplement. However, forage quality varies greatly among and within forage crops, and nutritional needs vary among and within animal species and classes. Producing suitable quality forage for a given situation requires knowing the factors that affect forage quality, then exercising management accordingly. Analyzing forages for nutrient content can be used to determine whether quality is adequate and to guide proper ration supplementation. Whole-plant corn harvested as corn silage is a key ration component for many rations fed to dairy cattle as a high-energy forage source having a high yield potential per hectare compared to other forages. Standard breeding techniques and bio-technology capabilities have provided new opportunities to dramatically alter corn silage composition. Various corn hybrids are available for use as corn silage in dairy cattle diets including: Waxy, High Lysine, Brown Midrib, High Oil, Starch Types, Leafy, and Floury. Continuous corn hybrid selection for corn silage has increasingly improved neutral detergent fiber digestibility (NDFD), in addition to higher grain content and overall dry matter (DM) yield (Nennich et al., 2003). The nutrients supplied by the ration are the multiplication of dry matter intake (DMI), nutrients concentration, and nutrients digestibility. The scientific literature contains several studies comparing different corn silage hybrids influencing dairy cattle performance (Barriere et al., 1995; Oba and Allen, 1999a; Kuehn et al., 1999; Bal et al., 2000b; Ballard et al., 2001; Thomas et al., 2001; Clark et al., 2002; Holt et al., 2013; Gorniak et al., 2014; Morrison et al., 2014; Ferraretto et al., 2015). Most studies have shown little change in milk yield (Kuehn et al., 1999; Bal et al., 2000b; Ballard et al., 2001), higher milk yield (Thomas et al., 2001; Clark et al., 2001), no improvement on DMI (Kuehn et al., 1999; Bal et al., 2000b; Thomas et al., 2001), higher DMI (Ballard et al., 2001; Clark et al. 2002) when feeding leafy corn silage to lactating dairy cows compared to conventional silage. Although past research has not shown a consistent increase in milk production or DMI when feeding a particular corn silage hybrid, improved corn silage hybrids are introduced to the marketplace every year. With the release of these new corn hybrids, it is essential to evaluate their agronomic traits, as well as, the impact on dairy cattle performance.

The world’s population is predicted to reach more than 9.2 billion by the year 2050 and we need to fulfill their food requirements through same or less land area by utilizing newly developed technology on farming. Intensification of land use is an excellent approach to increase productivity and labor utilization per unit of available land. Intercropping and mixed cropping used to produce quality forage blends have been practiced in the past decades to improve the yield and nutrient composition of the forage. Intercropping and mixed cropping of cereal crops with legumes increases overall productivity per unit of land through better utilization of soil nutrients and light, minimization of crop failure, reduction in weed infestation, and stabilization of the yield. Intercropping of corn with soybean has a number of benefits, such as low N fertilizer requirements, increased silage yield and better silage quality compared to mono-cropped corn. Numerous studies have reported that intercropping of soybean with corn increased the biomass yield by 20 to 40% (Singh et al., 1986) and CP by 11 to 15% (Putnam et al., 1986). The reason for increased silage yield with intercropping compared to monocropping is due to efficient utilization of available sunlight, moisture and nutrients in soil (Etebari and Tansi, 1994). Silage quality and CP concentration increased when soybeans were planted with corn in alternate rows as 1 corn - 1 soybean or 1 corn - 2 soybean rows compared to sole cropping of corn (Altinok et al., 2005). Smith (2000) reported increased silage yield and CP yield, while intercropping corn and pole bean together. However, intercropping of corn and soybean together generally produced less DM yield but higher quality silage (increased CP). Practicing alternate row sowings and benefiting from climbing types of legumes as component crop had better performances than same row sowings and dwarf type legume (Geren et al., 2008).

The overall objectives of studies included in this dissertation were to increase the feed efficiency in lactating dairy cows through production of appropriate corn-soybean forage blend, improved water quality and forage quality.

CHAPTER 1

LITERATURE REVIEW

Water quality

Water quality refers to the form of the water, including chemical, physical, and biological characteristics, usually with respect to its fitness for a particular purpose, such as drinking, washing, bathing, swimming or for irrigation. Water quality may be affected by several factors including taste, smell, turbidity, electrical conductivity, and presence or absence of certain substances. Recently, water quality is becoming a greater issue because of rapid mineral plant development and urbanization, which are responsible for degrading the quality of drinking water from different sources. Livestock forced to drink low quality contaminated water resulted in compromises in health and productivity. Water quality standards, as publicized by various educational and regulatory institutions, are often established upon science that is several years old and not in user friendly version (Gharibi et al., 2012).

Lactating dairy cows have the highest need for water because water is the major constituent (56 - 81%) of the body and milk production has about 87% water (Murphy, 1992). Lactating dairy cows roughly consume 100 L of water per day (Kramer et al., 2008). Therefore, it is crucial to supply adequate amounts of quality drinking water for lactating cows to maintain milk production. On top of quantity of water, the quality of water provided to lactating dairy cows is very important, because it directly affects the productivity and wellness of dairy cows (NRC, 2001). The water quality is usually estimated through five major characteristics namely: organoleptic properties (odor and taste), physiochemical characteristics (pH, total dissolved solids , total dissolved oxygen, and hardness), the presence of toxic compounds (heavy metals, toxic minerals, organophosphates, hydrocarbons, and pesticides), the presence of excessive amounts of minerals (such as nitrates, sodium, sulfates, iron, phosphate, and fluoride), and the microbial contents and contaminants in the water (NRC, 2001). Toxic metals/minerals and pathogenic microbes are the most harmful agents that depress water quality. Heavy metals like cadmium (Cd), chromium (Cr), lead (Pb), and mercury (Hg) have a tendency to accumulate in animal's living tissues and products, such as milk and meat, which can possibly transfer to human body through their consumption, and consecutively causing negative effects on wellness of both animals and human beings (Friberg et al., 1985, 1986; Lopez-Alonsoa et al., 2003; Mahaffey, 1985; NRC, 2005; Sharma et al., 1979). Bacterial contamination of the water not only affects dairy cattle, but also causes human infection through food-borne diseases (Crump et al., 2002). Therefore, in order to determine the sanitary quality, microbiologic analysis of water for coliform bacteria and other microorganisms is quite critical. Other factors, such as salinity (or TDS), nitrate, and H_2S, are also believed to have adverse effects on cattle's health and productivity (NRC, 2001). Therefore, toxic compounds and pathogenic microbial aspects should be given higher priority when evaluating the drinking water quality for lactating dairy cows (Gharibi et al., 2012).

Importance of water

Water is possibly the most important essential nutrient for all terrestrial animals. The water requirement of a high producing dairy cow per unit of body mass is greatest among land-based mammals (Woodford et al., 1985) because of the high volume of milk production, which contain about 87% water. Water is also essential for digestion, nutrient metabolism, transportation of nutrients and metabolites to and from tissues, removal of waste products through urine, feces, and respiration, maintenance of proper ion balance, fluid, and heat balance and provides fluid and cushioning environment for the developing fetus (Houpt, 1984; Murphy, 1992). The water concentration in a mature dairy cow ranges from 56 to 81% of body weight depending upon growth and/or lactation stage (Murphy, 1992). Loss of only about 20% of total body water is considered fatal to the cow (Beede, 2006). Lactating animals generally acquire water from three sources namely: voluntarily consumed drinking water, water present in feeds, and metabolic water formed within the body as a result of oxidation processes. Water intake through voluntarily drink and the feeds are the most important from a management point of view. Failure to follow to sound water management practices can inhibit animal performance. Ensley (2000) reported elevated milk yield with increased frequency of cleaning the water trough. Additionally, increased water space per cow has been found to have a positive impact on milk production, whereas increasing the distance from the feed bunk to first available water source had a negative effect on milk production (Ensley, 2000).

Factors affecting water intake

Water is often overlooked as an essential nutrient. Low water intake may limit milk yield and growth, and adversely affect health. Animals need a plentiful supply of good, clean water for normal rumen fermentation and metabolism, proper flow of feed through the digestive tract, good nutrients digestion and absorption, normal blood volume, and tissue needs (Adams and Sharpe, 1995). Lactating dairy cows normally consume large amounts of water. Many biotic (animal) and abiotic (environmental) factors have been reported as modulators of water intake. Among those DMI, nature of the diet, milk production, ambient temperature, and relative humidity are considered the most important (Castle, 1972; Castle and Thomas, 1975; Little and Shaw, 1978; Maust et al., 1972). Little and Shaw (1972) reported a correlation between water intake and both DMI and milk yield. They reported a non-significant correlation between water intake and body size, DM content of the feed, or mean air temperature. The final two variables had narrow ranges: 833 to 898 g/kg and 7 to 20 ^{o}C. A multiple regression model was developed for variables significantly correlated with water consumption, but it has been difficult to assess the degree of confidence to be placed in its application because a coefficient of multiple determination (R^2) was not reported (Murphy et al., 1983). Problems with water supply equipment, inadequate water pressure, low chemical quality, pollution, and stray voltage were major causes of low water consumption by dairy animal (Adams and Sharpe, 1995). Signs of inadequate water intake by dairy animals include firm and constipated manure, low urine output, infrequent drinking of water, high packed cell volume, unexplained drop in milk production and drinking of urine (Adams and Sharpe, 1995).

Effects of water restriction on animal production

Water consumption is closely associated with DMI in both beef (Brew et al., 2011) and dairy cows (Stockdale and King, 1983) and it is crucial to provide palatable water to livestock to maintain growth and milk production. Factors affecting voluntary water intake are animal factors, such as milk production (Dahlborn et al., 1998; Meyer et al. 2004) and body weight (Meyer et al., 2004), as well as external factors, such as climate conditions (Blackshaw and Blackshaw 1994), DM content of the ration (Dahlborn et al., 1998) and design of water trough (Pinheiro Machado Filho et al., 2004; Teixeira et al., 2006). It is therefore difficult to determine what water consumption levels are normal. Water intake data reported in the literature ranges between 19 to 41 L/d depending on season for beef cattle (Hoffman and Self, 1972; Ali et al., 1994; Brew et al., 2011), and 54 to 114 L/d for lactating dairy cows (Muller et al., 1994; Pinheiro Machado Filho et al., 2004; Cardot et al., 2008; Morris et al., 2010) divided into 3 to 7 drinking bouts on average (Jago et al. 2005; Cardot et al., 2008). Feeding management also affects water consumption. Cows that were fed a total mixed ration (TMR) consumed more often (5.2 times/d) than pasture fed cows (3.5 times/d) and had higher water intakes (TMR: 73 L/cow/day, grass: 53.7 L/cow/day, respectively; Jago et al., 2005). Similarly, water intake is affected by climate and increases in ambient temperature (Ali et al., 1994; Bicudo et al., 2003; Arias and Mader, 2011), in particular when animals have no access to shade (Hoffman and Self, 1972; Muller et al., 1994). Water scarcity affects the health, behavior and performance of cattle. Severe water restriction may decrease DMI (Utley et al., 1970; Little et al., 1978), milk production (Little et al., 1978; Little et al., 1980), body weight (Little et al., 1980; Little et al., 1984) and cause a change in behavior, such as increased aggression around the water trough and less lying (Little et al., 1980).

Estimation of water requirements

The factorial summation of the amounts of water needed for maintenance, growth, pregnancy, and lactation is the most common expression of the water requirement of a livestock (Murphy et al., 1983; NRC, 2001; Meyer et al., 2004).

Water balance = (Free drinking water + water on consumed diets + metabolic water) − (water excreted in urine and manure + water secreted in milk, sweat, and respiration)

Castle and Thomas (1975), Little and Shaw (1978), Murphy et al. (1983), Stockdale and King (1983), Holter and Urban (1992), and Dahlborn, et al. (1998) heavily contributed developing equations to predict the water intake of lactating dairy cows. The equations considered DMI, DM of the ration, milk yield, environmental conditions and sodium intake as factors affecting water consumption. The Dairy NRC (2001) suggested using equation developed by Murphy et al. (1983) when estimating the water intake of lactating dairy cows, where the regression coefficient for milk yield is much closer to the water content of milk.

Murphy et al. (1983) developed the following equation to predict free water intake for lactating dairy cows:

Free water intake (kg/d) = 15.99 + (1.58 × DMI, kg/d) + (0.9 × milk, kg/d) + (0.05 × Na intake, g/d) + (1.20 × minimum temperature in ^{o}C)

Holter and Urban (1992) developed the following equation to predict free water intake for dry cows:

Free water intake (kg/d) = -10.34 + (0.2296 × DM % of ration) + 0.2212 × DMI (kg/d) + (0.03944 × (CP% of ration)^{2})

Lactating dairy cattle need more water than any other nutrients, and it is the largest component of milk and manure (Van Horn et al., 1994). Young stock, transition, and lactating dairy cattle have generally increased metabolic rates, higher water turnover rate, require plenty of water intake compared with other stages of production (Squires, 1988). Factors affecting the water needs of lactating dairy cows are animal (body size, amount of milk produced, and rate of DMI etc.), diets (diet type, forage concentrate ratio, moisture content, sodium and nitrogen contents of the diet etc.) and environment (ambient temperature, relative humidity, season of the year etc.). Variation in water requirements between dairy and beef cows is mainly due to different demands for the rate and composition of body gain and for the magnitude of milk production (Beede, 2012). Cardot et al. (2008) predicted water intake and water requirement on their study which was similar to several previously published equations for lactating dairy cows. The most significant factors influencing free drinking water intake are ration DMI and milk production. On an average from several studies, the ratios of DMI to water intake and milk yield to water intake were 4.1, and 2.8, respectively (Beede, 2012). Considerable inconsistency was found among all studies and water composition was not reported for most of the studies.

Importance of water quality

Water is the most important nutrient for lactating dairy animals (NRC, 2001). However, good quality water is considered an inadequate commodity in many parts of the United States, as well as, other parts of the world (Murphy, 1992). In many regions of the United States, availability of plenty, clean, drinking water may become a challenge for tomorrow, as dairy farms are forced to move away from highly populated areas (Beede, 2005). Sources of water contamination can also affect animal production performance, as well as, wellness (Challis et al., 1987; Solomon et al., 1995; NRC, 2001). The lack of controlled research studies makes it difficult to evaluate the importance of water quality in dairy herds (Chase, 2002; Socha et al., 2003). Some dairy nutritionists don't care about mineral content of water, while formulating the ration because of a belief that they are not biologically available to cows. However in some cases, minerals in water are more biologically available for cows compared to feeds (NRC, 2001). The prediction of mineral excretion in dairy animals and the chemical composition of manure need to be considered as important as protein or energy dietary balances (Castillo et al., 2007), because they are eventually sources of water contamination. Thus, it isn't surprising that water quality plays a significant role in animal health and productivity.

Effects of water quality on animal production

Water for animals can be obtained from surface water (streams and ponds) or groundwater (wells). Water quality is mostly affected by its source and contamination from abiotic and biotic factors as a result of either dissolved nutrients or direct deposition of urine or feces containing nutrients and possibly microorganisms (Willms et al., 2002). Levels of dissolved salts may be high or low in groundwater depending on the geology of the adjacent area, rainfall pattern, vegetation types and topography. Human activities around the water sources will also influence the water quality. Evaluation of water quality usually includes measurements of salinity, hardness, pH, microbiological quality, algae, and nitrate and nitrite levels. High salt contents can affect both water consumption and

DMI and subsequent ADG (Willms et al., 2002). Graf and Holdaway (1952) and Allen et al. (1958) studied the potential effects of the hardness of the water and reported no effect of hardness (190 and 290 ppm compared to 0 ppm) on dairy cow milk yield, ADG or water intake. High nitrate levels in water are not common, but may occur and are often associated with extensive use of nitrogen fertilizers and manures, intensive livestock operations and can affect the quality and palatability of water (Wright, 2007).

Water infested with algae bloom may expose livestock to liver or neurotoxins produced by *Cyaonobacterium* spp., such as *Anabaena*, *Microcystis* and *Nodularia* (Zin and Edwards, 1979). The effect of subclinical doses of these toxins on animal performance and water palatability is not well understood. Water borne microbes such as *Leptospira* family (reproductive problems) and *Fusobacterium necrophorum* (foot rot and lameness) often use water and mud as a means of transfer (Wright, 2007). In addition, cattle are commonly hosts to *Giardia* spp., *Cryptosporidium* spp, nematodes and other parasites that affect their health and that are spread in water. *Giardia* and *Cryptosporidium* cause diarrhea in calves and lambs (Olson et al., 1995; Olson et al., 1997). If livestock has direct access to waterways the risk of fecal contamination is high. In fact, cattle will avoid drinking water that is contaminated with feces (0.05 mg/g water) when given a choice of clean water (Willms et al., 2002). When the animals had no choice, but to drink contaminated water, water consumption was reduced at manure concentrations above 2.5 mg/g water whereas a reduction in feed consumption occurred at concentrations greater than 5 mg/g water (Willms et al., 2002). Similar findings were demonstrated by Holechek (1980) who reported a decrease in water intake and ADG of cattle drinking from a water source contaminated with feces and urine. Willms et al.

(2002) studied the effects of clean water (water delivered to a trough from a well, river or stream), pond water pumped to a trough, or direct access to the pond on beef cattle productivity and reported that yearling heifers having access to clean water gained 23 and 20% more weight than those with direct access to the pond and having pond water pumped to a trough, respectively.

Lardner et al. (2005) used the same pond water to create 4 treatments: a) treated water by aeration, b) treated water by coagulation in combination with chlorine treatment, c) pond water pumped to a trough, and d) direct access to the pond, and studied the effects of these treatments on beef cattle in two separate experiments (yearlings and cow-calf pairs). Levels of *Escherichia Coli* in the pond were reduced with increasing water quality treatment of the coagulated and aerated water, however the water treatment did not influence infection by *Trichostrongyle*, *Eimeria*, *Cryptosporidium* or *Nematodirus* spp. in steers, cows or calves. Treated water improved weight gains by 9% over untreated water from the pond in three of five years. There was also an interesting effect of season, the steers with the treated water gained significantly more weight in the early part of the summer compared to the later part. Furthermore, steers that had access to aerated water tended to spend more time grazing and less time resting than steers that had direct access to the pond. Porath et al. (2002) demonstrated that the provision of off-stream water and trace-mineral salt improved weight gain in cows and calves by 11.5 kg and 0.14 kg/d, respectively. In conclusion, the positive effects of drinking clean water is because of an increase in palatability and water consumption, which subsequently, will lead to increased DMI and improved animal productivity (Willms et al., 2002; Lardner et al., 2005). However, performance advantages will most likely to occur in the years where production and quality forage is adequate.

Factors affecting water quality

Water is the most essential nutrient for cattle, but providing clean safe water for cattle is often overlooked. Most problems will occur in the summer when pond water is contaminated with manure, dissolved solids, nitrates, algae or sulfates. Poor water quality can lead to poor performance and poor reproduction that often goes unnoticed, but that can be deadly as well. Special attention should be given to water quality during the hot summer months when most problems occur. Using the best quality of water available will contribute to the optimal production of cattle. Drinking water quality should be part of an evaluation when there is a problem with poor cattle performance. The only way to know if a problem exists is to test the water for anti-quality factors (Dyer, 2012). During a drought, water quality declines as the concentration of pollutants increases when water evaporates and becomes stagnant. Many compounds in water can negatively affect cattle performance and health.

Salinity/total dissolved solids/total soluble salts

Salinity, total dissolved solids (TDS), and total soluble salts (TSS) are physiochemical characteristics of water which are used synonymously to measure the amount of salt, bicarbonate, sulfate, calcium, magnesium, silica, iron, nitrate, strontium, potassium, carbonate, potassium, boron and fluoride in water (NRC, 2001). Salinity refers to the mass of dissolved components contained in a solution and is typically determined indirectly by measuring total dissolved solids (TDS), total soluble salts (TSS), or electrical conductivity (EC). Salinity is often due to sodium chloride, but bicarbonate, sulfate, calcium, magnesium, and silica levels may also be significant. A lower percentage of salinity might include iron, nitrate, potassium, phosphorus, boron, strontium, and fluoride (NRC, 2001).

Water containing high levels of TDS is commonly found in wells in coastal regions, and can lower feed intake and production of cattle (Dyer, 2012). The upper desired level for TDS or TSS as measures of water quality can vary from approximately 1000 to 3000 ppm. A total dissolved solid is a crude estimate of water quality and is basically a measure of the soluble, non-organic constituents found in water. These dissolved constituents include bicarbonate (HCO_3^-), boron (B), calcium (Ca), carbonate (CO_3), fluoride (F), magnesium (Mg), nitrate (NO_3), iron (Fe), phosphorus (P), potassium (K), silica (SiO_2), sodium (Na), strontium (Sr) and sulfate (SO_4) most of the time (NRC, 1974). The studies conducted to determine the effects of TDS on the performance of lactating dairy cows came up with different results on water consumption, DMI, and milk yield. High levels of TDS combined with high temperature have negative effect on milk production (Solomon et al., 1995; Sanchez et al., 1994; Challis et al., 1987). Feed intake and production is not affected if the TDS level is below 3,000 ppm; however, it is not recommended to use water containing a TDS level greater than 5,000 ppm for cattle and TDS level >7000 ppm is unacceptable for all cattle (NRC, 2001). Previous studies have shown that TDS in the 4,000 to 5,000 ppm range lowered body weight gain in beef cattle and decreased milk production in lactating cows (Dyer, 2012). A high-level of SBM supplementation (0.4% BW) counteracted the detrimental effect of high TDS in drinking water on low-quality forage consumption by cattle (Lopez et al., 2014).

Hardness

Hardness is a measure of the concentration of divalent metallic cations dissolved in water and is generally expressed as the sum of calcium and magnesium concentrations expressed as equivalents of calcium carbonate. Other divalent metallic cations, such as Zinc, iron, strontium, aluminum, and manganese, can contribute to hardness, but concentrations are usually much lower than calcium and magnesium (NRC, 2001). National Research Council (2001) classified water as soft at 0-60 ppm, moderately hard at 61-120 ppm, hard at 121-180 ppm, and very hard at >180 ppm. Trace element nutrition research indicates that waters with high iron concentrations (> 0.3 mg/L) can affect cattle health and performance by impacting copper and zinc absorption. Limited research also suggested that high levels of dietary calcium consumption (> 12.5 g calcium/kg diet) can reduce selenium absorption. Hard waters can also be problematic in low pressure and low flow watering systems due to the accumulation of insoluble calcium and magnesium carbonate deposits (Higgins, and Agouridis, 2008).

Nitrates

Although, many species of livestock are susceptible to nitrate poisoning, cattle are affected most frequently. Ruminants are more vulnerable because rumen microbes reduces nitrate to ammonia, with nitrite being intermediate product. Nitrite is ~10 folds more toxic than nitrate (Thompson, 2014). Nitrates from manure and fertilizer are an increasing problem affecting water quality. During periods of drought, pond water and streams become stagnant and evaporate, resulting in higher concentrations of pollutants such as nitrates. Water with nitrate- nitrogen concentrations of less than 10 mg/L, and nitrate concentrations of less than 44 mg/L are generally safe for dairy cows (NRC, 2001). Nitrate level of 300 ppm is considered unsafe, less than 100 ppm safe and 100-300 ppm is questionable for cattle (Dyer, 2012).

When pasture or feed that is high in nitrates is fed, water contamination can become a serious problem. Death can occur when cattle consume water high in nitrates, but chronic toxicity is more common. Chronic toxicity causes the animal to eat less and thus have lower performance. Younger cattle are much more susceptible to nitrate poisoning (Dyer, 2012). When excessive levels of nitrates are present, nitrites can accumulate in the rumen as intermediate product between nitrate and ammonia. Nitrites absorbed into the bloodstream interfere with the oxygen-transporting capacity of hemoglobin, thus interfering with respiration. In severe cases, asphyxiation can occur. Moderate levels of nitrate poisoning have been linked to a host of problems including poor growth, infertility, abortions, and vitamin A deficiencies (Higgins and Agouridis, 2008). Signs of acute nitrate poisoning include labored breathing, rapid pulse, frothing at the mouth, convulsion, blue muzzle, and a blue tint around the eyes. Signs of chronic nitrate poisoning are generally not as evident, but can include reduced weight gain, decreased appetite, lower milk production, and increased susceptibility to infection (Higgins and Agouridis, 2008).

Mineral contents

Other materials that cause water quality problems include sulfur, iron and manganese (Dyer, 2012). These minerals decrease water intake because of foul flavors and/or odor. Another common problem is excessive levels of minerals that interfere with normal mineral absorption and lead to deficiencies. This is most common with high iron and sulfate levels that bind and prevent the absorption of copper and zinc (Dyer, 2012). Although it was known that higher levels of Fe and Mn in water negatively impacts animal production, the literature debates the impact on animal performance. Some research relies on fact that the Fe in water (ferrous form) is more reactive and readily available to the cow than Fe found in ration and supplements. Consumption of large amounts of ferrous Fe increases the risk of toxicity as the highly soluble ferrous Fe can be readily absorbed by sneaking between the cells lining the gut and escaping normal cellular regulation (Beede, 2006). Excessive amounts of absorbed Fe can overload the body's capacity to bind Fe, which eventually generates huge amounts of reactive oxygen species that can heavily damage the cell membranes and disturb the normal biochemical pathways (Beede, 2006). Another group of researchers belief that although Fe found in water has greater availability and reactivity, the quantity of Fe supplied by most water is relatively low. The primary reason for reduced animal performance when consuming water having less than 5 ppm Fe is reduced palatability that reduced water consumption.

Sulfate is present in most water sources and is commonly found in the form of Ca, Fe, Na, and Mg salts, while H_2S is the most toxic form (NRC, 2001). Elevated levels of these salts can make the water taste objectionable to cattle. Guidelines for SO_4 in water are not well defined, but high concentrations cause diarrhea and in some instances Cu deficiencies. High SO_4 concentrations result in the development of polioencephalomalacia (PEM), which is a neurological disorder characterized by weakness, muscle tremors, lethargy, and even paralysis and death. High SO_4 water consumption often requires changes to the supplied mineral mix. The form of S is also important in determining toxicity. Sulfur in the form of H_2S can lead to reduced water intake at levels as low as 0.1 mg/L (Higgins and Agouridis, 2008).

Most of the water available on rangelands to drink by cattle is contaminated with SO_4 salts. Water intake by cattle starts to decrease at SO_4 levels of 2,500 to 3,000 mg/L (Weeth and Hunter, 1971; Harper et al., 1997) and declines further at greater levels (Embry et al., 1959). When cattle consume high SO_4 water for more than 7 days, DMI was reduced with lower BW gains (Embry et al., 1959; Weeth and Hunter, 1971), scours (Embry et al., 1959), diuresis (Weeth and Hunter, 1971), and suboptimal production (Loneragan et al., 2001). High levels of dietary S coming from the water source have been implicated in reducing net energy values (Zinn et al., 1997), interference with mineral status (Smart et al., 1986; Ivancic and Weiss, 2001), and development of polioencephalomalacia (Olkowski, 1997). Increasing concentrations of $MgSO_4$ in drinking water can potentially reduce water consumption by cattle (Grout et al., 2006).

On the other hand, water can be a noteworthy source of minerals when we consider the amount contributed when the maximum mineral content was observed. For instance, US water samples with the maximum observed Cu, Fe, Na and S content would contribute 545, 3487, 314 and 444%, respectively, of the cow's requirements for these minerals and would reduce the dietary DCAD by 610 meq/kg OM (Socha et al., 2003). High level of nitrate intakes may inhibit I uptake by the thyroid gland (Puls, 1994). High intakes of Fe and S can upset the availability of Zn, Mn, Cu and Se (NRC, 2001; Puls, 1994). Elevating dietary S concentration from 0.2% to 0.4% due to intake of high sulfate water decreases the absorption coefficient of Cu from 4.6% to 3.1 %. If cattle were not feed complexed Cu (CuEDTA), dietary Cu levels would need to be increased by 32.6% in order to meet the Cu requirements of cattle. In some of these cases, water can add enough mineral to generate mineral toxicity. The Nutrient Requirements of Dairy Cattle (2001) lists the maximum tolerable level for S to be 0.4%. If cattle are consuming 104 kg of water containing 1000 ppm of S (3000 ppm sulfate), they would be consuming 104 g of S from water. Water's contribution to dietary intake of S alone would result in a dietary S concentration of 0.46% OM, assuming cows are consuming 50 lbs of OM (Socha et al., 2003).

Microbial population

Water sources for agriculture animals should be examined for bacterial loads because bacteria in water can cause different health problems in animals including intestinal infections, dysentery, and hepatitis. The maximum tolerance level of bacterial load in water is directly depend upon type of bacteria, animal and state of health with calves and post-fresh cows being less tolerant than mid to late lactation cows (Mancl, 1989). Coliform in water can originate from animal/human waste, soil or decaying vegetation. Coliforms may not cause disease but can be indicators of pathogenic organisms (Mancl, 1989). Testing for fecal *Streptococci* can determine if the source of fecal coliform is human or animal. If the ratio of fecal coliform to fecal *Streptococci* is near 4, the source of the fecal coliform is human. If it is less than 1, source of fecal coliform is animal (Mancl, 1989).

Water temperature

When the air temperature increases above 4.4°C, cattle consume additional water based on dry matter consumption. Cattle typically prefer drinking water at temperatures between 4.4°C and 18.3°C. When the temperature is more than 27°C, water and feed intake rates often decrease, affecting animal productivity (Higgins and Agouridis, 2008). Wilks et al. (1990) studied the effect of water temperature on preference for drinking and reported that dairy cow preferred warm water 97% of the time when offered warm and chilled water as cafeteria style in warm weather. Cool water helps cattle maintain proper body temperature and leads to increased water intake. During heat stress, chilled water (27 - 29 ^{o}C) may reduce body temperature for a maximum of 2.2 h which was not long enough to make a significant impact on body temperature (Stermer et al., 1986). Shallow ponds or small water troughs can heat up in the summer and lead to decreased water intake. Deep ponds and groundwater pumped into large water tanks do not generally heat up enough to affect water intake (Dyer, 2012).

Algae

Blue-green algae are a water quality problem usually seen in surface water that is rich in nutrients (Bergsrud and Linn, 1990). The nature of harmful algal blooms in estuaries and coastal waters has altered over the past two decades including the number of blooms, the economic losses from blooms, the types of water resources affected, and the number and types of toxin producing species (Boesch et al., 1997). The nutrients from human and agricultural activities that are enriching waters sources are believed to play an important role in algal blooms. Suitable temperature for algae growth occur in the upper United States from May through early November, although waters with high levels of nutrients can experience algal blooms with cooler water temperatures (Bergsrud and Linn, 1990). Algal blooms can occur almost overnight and algae can concentrate along downwind shores of lakes, ponds and streams (Bergsrud and Linn, 1990). The algae species of most concern are the blue-green algae as they can cause muscle tremors, diarrhea, labored breathing, lack of coordination, liver damage and death in livestock (Bergsrud and Linn, 1990). Effects can occur within a few minutes to a day and animals that survive may shed large sections of unpigmented (white) areas of their hides (Bergsrud and Linn, 1990). Nontoxic algae in drinking water can also be a concern, but blue-green algae under the right conditions; can potentially produce toxins that can kill animals. Toxicity problems usually occur when cattle consume large amounts of the algae in the summer or early fall following a rapid bloom of algae. Algae can give water an undesirable taste, odor, color or texture (Palmer, 1962). In addition, algae can reduce water flow by clogging screens and filters and interfere with chlorination (Palmer, 1962). The best methods to control algae are to eliminate the nutrient source entering the water, aerate the water or fence the cattle away from the pond and pump water to a tank (Dyer, 2012).

Pond versus trough

Ponds are an important source of water for many cattle herds. Use of fencing to prevent cattle gaining access to ponds helps to reduce sedimentation and improve water quality. A pipe can be installed to run drinking water to a tank at the base of the dam. Researchers showed 9 % higher body weight gain in nursing calves when the drinking water for the cow-calf pairs came from a trough compared to cattle drinking directly from a pond (Dyer, 2012).

Water treatment systems

Different types of water treatment systems are available to eliminate or reduce the potential contaminants from water. Some water treatment systems are very costly and may require substantial equipment maintenance. Selection of the appropriate water treatment system is affected by chemical composition of tested water, cost effectiveness, health and production benefits for cattle. Choices for treating dairy cattle drinking water are mostly determined by the contaminant present to the water. A brief overview on drinking water treatment methods is presented in Table 1.1.

Disinfection

The process of killing (inactivating) harmful and objectionable bacteria, cysts and other pathogenic microorganisms from water by various agents, such as chemicals, heat, ultraviolet light, ultrasonic waves, or radiation, is called disinfection. The most common chemical disinfectant used to treat water is chlorine. The non-chemical disinfectant process is with thermal treatment, ultraviolet light, ultrasonic waves, or radiation. The cleanliness of water container/source is ultimately the indicator of the effectiveness of the use of disinfectants. Long-term use of disinfectants in long run is not recommended because for instance chlorine can combine with organic matter in water to form trihalomethanes which are considered carcinogenic (Bergsrud and Linn, 1990).

Chlorine

Chlorine is a powerful oxidizing agent and the most commonly used disinfectant, because of its low cost and effectiveness at low concentrations. In addition, if applied in a sufficient dose, chlorine has a residual effect. Therefore, chlorine remaining in the water can continue to destroy bacteria (Reynolds and Richards, 1996). Although chlorine is inexpensive, chlorination requires a contact tank that allows the chlorine time to disinfect the water. Additional maintenance is neither difficult nor expensive (Mancl and Eastridge, 1993). Chlorine in water is over three times more effective as a disinfectant against *Escherichia coli* than an equivalent concentration of bromine, and over six times more effective than an equivalent concentration of iodine (Koski et al., 1966).

Hydrogen peroxide

Hydrogen peroxide (H_2O_2) is a powerful oxidizing agent, much more powerful than aeration, chlorine or potassium permanganate. Hydrogen peroxide decomposes into oxygen and water leaving no trace of a chemical residue. For problem waters containing iron, bacteria, manganese, and hydrogen sulfide gas, H_2O_2 systems are an excellent choice. When H_2O_2 is added to water, a large amount of dissolved oxygen is released and a powerful oxidizing effect occurs. This type of iron filter system handles the absolute worst type of water reliably and effectively. Unlike chlorine, H_2O_2 leaves no salts, metals or chemical residuals. The only disadvantage is that it costs a little more than chlorine bleach (Westcott and Navratil, 2004).

Ultraviolet light

Ultraviolet (UV) light is produced using ultraviolet lamps with quartz covers. Ultraviolet light can be a viable method for disinfecting water (Mancl and Eastridge, 1993). However, the effectiveness of UV irradiation as a disinfectant is dependent on the ability of the radiation to pass through the water and contact microorganisms. Therefore, filtration may be necessary for cloudy or discolored water (Mancl and Eastridge, 1993). Also, UV light does not provide residual disinfection. UV produces a minimum of by-products when treating the water.

Distillation

Distillation is one of the oldest methods of treating water and is still in use. Distillation is a process of separating the component substances from a liquid mixture by selective evaporation and condensation which can effectively remove many water contaminants including bacteria, inorganic and organic compounds (Kamrin et al., 1990). During distillation water is boiled to form steam. The steam is captured, cooled and condensed to form water. Nitrates, sulfates and all other minerals are removed as they remain in the boiling tank.

Reverse osmosis

Reverse osmosis is a water purification technology through desalination that uses a semipermeable membrane to eliminate ions, molecules and larger particles from water (Greenlee et al., 2009). In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property, that is driven by a chemical potential and a thermodynamic parameter. Reverse osmosis can remove many types of molecules and ions from solutions, including bacteria, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. Reverse osmosis removes nitrates, sulfates and all other minerals by separating water from the saline solution (Greenlee et al., 2009).

Ion exchange system

Ion exchange systems can be used to decrease nitrates, sulfates, water hardness and TDS. The main components of an ion exchange system are an exchange column filled with ion exchange resin, waste storage tank and regeneration solution tank (Reynolds and Richards, 1996). During nitrate or sulfate reduction, these ions are usually exchanged with chlorine ions. However, during water softening, calcium and magnesium ions are exchanged for sodium ions. Waste brine containing contaminants removed from the water is stored in the waste storage tank and regeneration solution is used to recharge the resin.

Ozonation

Ozonation is used by many European countries and also in a few municipalities in the United States and Canada. This alternative is more cost effective and energy-intensive. It involves ozone being bubbled through the water, breaking down all parasites, bacteria, and all other harmful organic substances. However, this method leaves no residual ozone to control the contamination of the water after the process has been completed (Neumann, 1981).

Summary

Water is considered as most vital nutrient for both plant and animals. Water quality, as well as quantity, may affect DMI, milk production and animal health as poor water quality will normally result in reduced water and feed intake. When evaluating water quality for livestock, we need to consider DMI, production performance, wellness and health of animal, and safety of animal product for human consumption. Water quality problems affecting livestock are more commonly seen with high concentrations of minerals, high nitrogen, bacterial contamination, toxic blue-green algae, and accidental spills of petroleum, pesticides or fertilizers. Factors such as age of the animal, type of ration offered, state of growth or lactation, and type of species determine the tolerance of minerals in water. In the past, very little consideration was given to how drinking water should be provided and managed in cattle production systems because of its inexpensiveness and abundances. However, the concept is changed today and conservation of water resources is increasingly gaining more attention worldwide because of water pollution and scarcity. Some agricultural farms already considered water as a significant variable cost which will become more costly in the future. For the animal agriculture system, the accessibility, source, quantity, quality, consumption, treatment, and conservation of water will be significant factors limiting farm location, size, sustainability, and overall profitability. Cattle producers should be encouraged to improve the management and efficient use of clean drinking water by wisely utilizing and conserving as much as possible. Undoubtedly, the sustainability of animal agriculture in the future will directly depend on the efficient and judicious use of water to reduce the overall water footprint of each farm. Since global demand for clean drinking water is increasing day by day, it is our responsibility to conserve water by utilizing currently available techniques.

Forage quality

Feed is the single highest cost of milk production which accounts for approximately 50 to 70% of the total cost involved in milk production and forage typically make up the greatest percentage of the diets (Stone, 2010). Forages are the foundation upon which nutritionally sound, economical and rumen healthy rations are built. The quality and quantity of forages fed to the dairy herd is directly related to milk production, purchased feed costs, whole farm nutrient balance and profitability. Forages are the key to healthy and productive cows and profitable, successful dairying. Forage quality is defined in several ways, but is often poorly understood. Though very important, forage quality often gets far less attention than it deserves. The extent to which forage has the potential to produce a desired animal response is called forage quality. The better the forage quality, the more of it cows eat, the better the cow performs, and the less need for supplements. However, forage quality varies greatly among and within forage crops, and nutritional needs vary among and within animal species and classes. Producing suitable forage quality for a given situation requires knowing the factors that affect forage quality, then exercising management accordingly. Analyzing forages for nutrient content can be used to determine whether quality is adequate and to guide proper ration supplementation. Forage quality can impact dairy farmers through their effects on milk yield, feed costs, and health of dairy cows. Low quality forages are usually consumed slower and in reduced amount compared to high quality forages, which provides less nutrients to the dairy cows to produce milk.

Corn silage and its quality

Corn silage is a principal feed component in many rations fed to dairy cows, and its use continues to increase in high producing lactating dairy cow rations, especially in the United States. Numerous kinds of corn hybrids are available in the U.S. market to use as silage for dairy cow rations including brown midrib, leafy, floury, waxy, high lysine, and high oil hybrids. Lately, corn hybrids selection for silage has ever more focused on enhanced NDF digestibility in addition to high grain production and overall DM yield. Dairy cows are designed by nature to transform forages and other fibrous feeds into high quality products, such as milk and meat. Home grown forages are the most economical sources of energy and protein fed to the cow for most of the dairy farms in the United States. Innovation from recent forage quality studies and improved knowledge of how to better utilize forages in dairy rations moved the use of forage from low to high levels across dairy herds. A primary reason is that forage producers are doing a better job of harvesting, preserving and storing huge amounts of high quality forages. The accessibility and use of NDF digestibility has provided extra information to assist dairy nutritionist in utilizing higher levels of forages in the rations. There have also been improvements in the NDF digestibility and starch digestibility of corn silage hybrids and other forage cultivars available to forage producers through principle of plant breeding.

Feeding high forage diets are an opportunity that should be considered in many dairy herds to obtain higher income over feed cost. The concept of a high forage ration was developed to take advantage of the biology of the cow to convert forage into milk. The concept of a high forage ration will work if there is an adequate quantity of consistent, high quality forage available on the farm. In some farms, the transfer to feeding higher forage rations will take some times due to required modifications in the cropping, forage harvesting and forage storage systems currently available on the farm. The long-term potential returns from high quality high forage rations include higher levels of milk components, improved cow health, reproduction, and herd profitability. Forage quality can be best estimate by their potential DMI and DMD, which are influenced by the NDF and ADF content of the forage.

Importance of NDF digestibility

Since corn and other small grains prices are skyrocketing every year, dairy farmers, nutritionists and researchers are more interested in content of NDF, ADF, lignin, NDFD, DMD, non-structural carbohydrates (NSC), and starch digestibility than ever before. Currently, most of the commercial forage testing laboratories in the United States have begun to estimate the neutral detergent fiber digestibility (NDFD), along with NDF and ADF concentrations. Even though NDF and ADF are considered as good indicators of fiber concentration in forages, they are unable to measure digestibility of the fiber on that forage. More accurate estimates of total digestible nutrients (TDN), net energy (NE), and DMI potential can be accomplish through in vitro NDF digestibility. As a general rule, the higher the NDF digestibility, the higher digestible energy will be available to produce milk as the cow consumes more forage. With addition of forage NDFD value on ration formulation, ration balancing can be more precise with more predictable DMI and milk yield. Fiber is considered as an important element of the dairy cattle ration, and physically effective NDF is positively correlated with chewing activity, ruminal pH, and butter fat content (Mertens, 1997). On the contrary, to get greater physically effective NDF with longer forage particles may decrease DMI through reduced ruminal passage rate and increased rumen fill (Mertens,1987), and increase sorting of total mixed ration (Leonardi and Armentano, 2003) by dairy cows. The studies on length of cut of corn silage reported nominal advantages compared to longer length of cut on production performance (Bal et al., 2000a; Johnson et al., 2003a; Fernandez et al., 2004; Cooke and Bernard, 2005; Yang and Beauchemin, 2005). The impact of length of cut on NDF digestibility is imprecise in the studies, with reports of similar (Fernandez et al., 2004; Cooke and Bernard, 2005) or greater (Bal et al., 2000a; Johnson et al., 2003a; Yang and Beauchemin, 2005) NDFD with longer length of cut of corn silage.

Production of high NDF level corn silage could mean that lesser amounts of other forages would have to be produced or purchased by the dairy producers to meet NDF requirements of the cows (NRC, 2001). Corn hybrids with higher NDF levels are not commercially available on regular basis possibly because whole plant NDF level is negatively associated with seed yield (Cox et al., 1994), in vitro DMD (Cox et al., 1994; De Boever et al., 1996), and in vivo DMD (Aufrere et al., 1992; De Boever et al., 1996). On the other hand, whole plant NDF level is not associated with corn silage DM yield (Cox et al., 1994). In addition, in vitro and in vivo digestibility taken at low DMI might not signify digestibility in cows at high DMI. Tine et al. (2001) using BMR corn silage, disclosed clearly that generalizing digestibility data obtained from cows at maintenance intakes to cows at productive intakes is not applicable. In that study, hybrid differences were found for measured TDN and ME concentrations when all corn silage diets were fed to dry cows at maintenance, but no differences were detected when silages were fed as part of a mixed diet at 4× maintenance. Corn silage hybrids having higher NDF values could have economic significance as a fiber source, but that value would be decreased if the higher NDF values resulted in lower digestibility and ultimately lower available energy. Weiss and Wyatt (2002) reported similar digestibility, calculated NE_L values and milk production when cows fed a diet with 45% corn silage from a hybrid selected for higher concentrations of NDF and increased in vitro NDF digestibility while comparing with a diet with 45% corn silage from conventional hybrid. Ferraretto et al. (2015) reported overall similar apparent total-tract NDF digestibility in high-producing dairy cows fed a floury-leafy corn silage hybrid when compared with BMR corn silage hybrid.

Studies on five genetically different corn silage hybrids grown in 15 environmentally diverse locations in Michigan showed that the growing environment had a highly significant ($P < 0.01$) effect on yield, starch content and 24-hour neutral detergent fiber (NDF) digestibility (Bolinger et al., 2014). Lower precipitation (< 41 cm) during growing season had lower plant yields and milk/ha, but greater NDF digestibility (48.3% vs 45.8% of NDF).

Fiber digestibility plays a key role in maintaining a prosperous rumen environment. To maintain a perfect ruminal metabolism, ration fed to the cow should be balanced in terms of physically effective fiber and readily fermentable carbohydrates (Zebeli et al., 2006). Oba and Allen (2000) reported that NDFD can impact lactational performance of cows regardless of the overall concentration of NDF in the diet. In addition, Oba and Allen (1999b) mentioned that in vitro NDFD was associated with an increase in DMI by 0.17 kg. If NDF is more digestible, rumen fill would be decreased and DMI could be increased. The concentration, digestibility, and fragility of forage NDF contributes most to the rumen-filling effect of a diet (Holt et al., 2013). When compared with conventional corn silage, the BMR corn silage improved overall lactating performance of dairy cows because of higher in vitro NDFD that supply more digestible energy to produce more milk (Oba and Allen, 2000).

The NRC (2001) comprehensive energy equation was developed based on fiber digestibility using lignin. Whole-plant lignin concentration was reported to have a strong negative correlation with in vitro NDFD within evaluations of brown midrib (bm3) hybrids to other lines having similar genotype (Oba and Allen, 1999b). However, corn stover NDF and lignin contents increased while NDFD decreased with progressive maturity, but whole-plant NDF and lignin contents were constant or dropped as grain proportion increased (Russell et al., 1992; Hunt et al., 1989). Lignin as percentage of total NDF can explain only half or less of the variation for corn silage in vitro NDFD (Oba and

Allen, 2005; Allen and Oba, 1996). Morrison et al. (2014) recently compared leafy floury corn silage hybrid with BMR corn silage hybrid and reported that the BMR corn silage fed cows had higher total tract NDF digestibility compared to cows fed leafy floury corn silage.

Importance of Starch digestibility

Corn silage is the principal forage and source of energy used to feed the cows by dairy farmers in the United States (Johnson et al., 1999). Hence, corn silage is considered an important source of both energy and physically effective fiber in dairy cow rations. About 50% of corn silage energy value is derived from starch (NRC, 2001) and the rest of it from NDF, sugar and EE. Starch digestibility in corn silage is very important because about 50% of its energy value comes from the starch, which is supplied by the grain portion of whole plant corn silage. Thus, improving corn silage starch digestibility and NDF digestibility may improve production performance and decrease feed costs, especially during skyrocketing corn prices. Starch digestibility is directly related to the chemical and physical properties of the kernel. Kernel texture can fall anywhere along the range from highly digested (floury endosperm) to the more difficult to digest (vitreous endosperm). Depending on the time spent in the silo and the degree of processing, pieces of corn from vitreous hybrids may pass through in the manure, while the kernels from floury endosperm varieties tend to be digested much more completely.

Starch and NDF digestibility for corn silage based diets can be affected by corn types, maturity stage at harvest, theoretical length of cut, and kernel processing (Johnson et al., 1999). Harvesting of corn for silage at late maturity stage resulted in increased DM content and reduced apparent total-tract starch digestibility (Bal et al., 1997; Jensen et al., 2005), but not different as reported by Johnson et al. (2002). Mechanical processing affected the nutritive value of corn silage. The digestibility of the starch component of corn silage is affected predominantly by kernel processing and ensiling time (Ferraretto et al., 2014c; Ferraretto and Shaver, 2013; Ferraretto and Shaver, 2012). Moreover, the processing of corn silage improved total tract starch digestibility in some research (Bal et al., 2000a; Dhiman et al., 2000; Schwab et al., 2002), but not in all findings (Johnson et al., 2002; Johnson et al., 2003b; Ouellet et al., 2003). Several studies on past have shown improved starch digestibility due to processing with an onboard mechanical processor attached to a forage harvester (Doggett, 1998; Harrison et al., 1998; Young et al., 1998; Bal et al., 2000a; Dhiman et al., 2000). Weiss and Wyatt (2000) also reported significantly higher total tract digestibilities of starch and non-fiber carbohydrates for lactating cows fed mechanically processed conventional corn silage harvested at one-half mm compared with unprocessed corn silage. Mechanically processed corn silage increased TDN of the conventional corn silage diet by 5.3% (Weiss and Wyatt, 2000).

Recently, Ferraretto et al. (2015) reported an increase in apparent total-tract starch digestibility by 5 percentage units in high-producing dairy cows fed a floury-leafy corn silage hybrid compared with BMR in agreement with greater ruminal in vitro, in situ and in vivo starch digestibilities for floury-leafy corn silage. Morrison et al. (2014) compared leafy floury corn hybrid with BMR hybrid and reported that the BMR-fed cows had similar total tract starch digestibility compare to cow fed leafy floury corn silage TMR. Ferraretto et al. (2014b) compared leafy floury hybrid corn silage with BMR hybrid corn silage and reported greater in vivo starch digestibility with leafy floury corn hybrid silage compared to BMR hybrid corn silage.

Ferraretto et al. (2014a) reported that ruminal in vitro starch digestibility increased over time in fermented storage among four leafy and four brown mid-rib (BMR) hybrids and that ammonia-nitrogen and soluble protein were both good proxy indicators of in vitro starch digestibility. Klingensmith et al. (2014) reported no effect of storage time of two corn hybrids bred for varying amounts of floury and vitreous starch on their soluble starch, starch degradation rates, slowly digestible starch and resistant starch at in situ experiment. While differences for these measurements existed in fresh silage at harvest, there were no differences for any starch digestibility parameter between the two endosperm hybrids when measured after 54 days of storage.

Ruminal starch degradability of corn silage is significantly affected by the combined effects of ensiling time and whole plant dry matter at harvest. Doorenbos and van Laar (2014) studied the effect of ensiling time and harvest DM on the effective rumen degradability of starch and reported increased starch degradability from harvest (70.8%) and stabilized (86.3%) at 8 months of ensiled storage. Higher DM silages (40%) showed lower initial harvest starch degradability (61.3%), which also increased over time to stabilize at 78% at 8 months of storage. Studies on five genetically different corn silage hybrids grown in 15 environmentally diverse locations in Michigan showed that total accumulated growing degree days prior to harvest were positively related to starch content but negatively related to sugar content of the corn plant (Bolinger et al., 2014).

Selection of corn hybrids

A few decades ago, corn silage hybrids were selected on the basis that a best performing grain hybrid related to a best silage hybrid because of less corn silage performance, harvest and storage data available. However at present, corn hybrids are routinely tested for silage production and quality by the public and private areas and many dairy farmers grow and harvest corn for only silage purposes. Because of the above mentioned reason, corn breeders were encouraged to provide more emphasis on corn silage hybrid development and selection. Corn seed companies are trying to improve corn silage hybrid performance based on agronomic traits and feeding quality traits. Agronomic traits include total yield, grain yield, maturity, standability, disease resistance, insect resistance, herbicide resistance, dry-down rate and stay-green. Feeding quality traits include CP, NDF, NDF digestibility, in vitro digestibility, starch content and availability, kernel texture and milk/ton of silage. However, milk yield/acre is considered as compromise point between agronomical and quality traits, while selecting a superior corn silage hybrid.

Corn hybrids conventionally have been selected for both increased corn grain yield and whole-plant corn silage yield. Corn hybrids selected for high grain yield may not be the peak yielding hybrids for silage (Coors et al., 1994). Hunt et al. (1993) and Barriere et al. (1995) listed increased gain and feed efficiency in beef steers and DMI and milk yield in dairy cows, due to improvements in nutritive value of corn silage hybrid. Corn silage produced from BMR hybrids is renowned for its reduced lignin concentration and improved in vitro NDF digestibility (Oba and Allen, 1999a). However, evaluations of agronomic traits of bm3 hybrids have been discouraging because of poor grain and forage yields (Coors et al., 1994). Improved feed intake and milk yield have been reported for bm3 corn silage compared with its other same genotype lines (Oba and Allen, 1999a). Leafy corn hybrids have more leaves above the ear and, higher grain moisture content or softer kernel texture in some cases (Dwyer et al., 1998; Shaver, 1983).

A forage quality index, milk per ton of forage DM (Undersander et al., 1993), was established using an energy value of forage predicted from ADF concentration and DMI potential of forage predicted from NDF concentration as its basis. Schwab et al. (2003) modified the milk per ton quality index for corn silage later by using an energy value derived from summative equations (Schwab et al., 2003; NRC, 2001) and DMI predicted from both NDF concentration (Mertens, 1987) and in vitro NDF digestibility (Oba and Allen, 1999b) as its basis. The milk per ton quality index (MILK2000) developed by Schwab et al. (2003) has become a central point for corn silage hybrid performance trials and breeding programs in university and industry (Lauer et al., 2005).

Corn silage is a principle source of energy and effective fiber for many dairy cows in the United States. Selection of appropriate corn hybrids for silage is an important step for profitable dairy farming, as yield and quality of silage can vary greatly among the hybrids. In the meantime, corn silage is a principal source of energy for lactation performance and growth; dairy producers should estimate both silage yield and quality when selecting hybrids. Corn silage hybrids Selected for high available nutrients and mechanical processing of the whole corn plant are two methods that have been widely studied in recent years to improve the utilization of corn silage (Ebling and Kung, Jr., 2004). Making a decision between two hybrids having high NDFD versus high starch digestibility can be challenging because we don’t have any research publication that directly compares between NDFD and starch digestibility. Use of nitrogen fertilizer, growing stage at harvest, kernel processing and length of ensiling may affect the starch-protein matrix in corn kernels, which is directly related to starch digestibility in corn silage. Moreover, selection of corn silage hybrids having floury-type endosperm might be an option to increase starch digestibility. Higher starch digestibility associated with high available digestible energy to produce more milk and growth that results in improved feed efficiency. Hence, selection of corn silage hybrids for better starch digestibility may improve milk yield per acre, and thereby overall profitability of dairy farms. In addition, improvements in NDF digestibility through different harvest practices are possible, but inconsistent or minimal. However, selection of silage hybrids for high NDF digestibility has improved milk yield by dairy cows. Selection of silage hybrids with highly digestible NDF can reduce the effects of rumen fill in high-producing cows, thereby allowing for increased intake and milk production (Ferraretto et al., 2015).

Different characters used to evaluate corn silage quality can make selection of appropriate hybrids for particular dairy farms a little bit tough. It will be a good idea to take advice from dairy nutritionists during the hybrid selection process, which eventually helps to ensure that newly selected corn silage hybrid supplies the essential nutrients required by the dairy cows for milk production. Overall silage quality can be predicted via a distinct variable called milk/ton, which was calculated using the MILK2006 spreadsheet developed at the University of Wisconsin (Shaver et al., 2006). Milk/ton is an overall indication of silage quality, and it is estimated from forage analyses for crude protein (CP), neutral detergent fiber (NDF), NDF digestibility (NDFD), starch and non-fiber carbohydrate. Studies on five genetically different corn silage hybrids grown in 15 environmentally diverse locations in Michigan showed that the growing environment and harvest DM generally had greater impact on silage yield and nutritive value than hybrid choice among the corn silage hybrids tested. Hybrids with greater drought tolerance had greater starch content of plants and grain and greater starch availability from grain but lower NDF digestibility. Higher precipitation (36 to 65 cm) during growing period was negatively related to CP content and NDF digestibility, but positively related to yield and milk/ha (Bolinger et al., 2014).

Genetics of corn hybrids greatly affect total DM production and starch content of the silage. However, the growing situation can undermine genetics, particularly concerning fiber digestibility. Nutritionists and corn silage producers should become familiar with use of analytical methods to assess fiber digestibility in new crop corn silage. Research has clearly shown that tremendous variation also exists in starch digestibility, but unlike NDF digestibility, it continues to increase for the first six to eight months of storage (Mahana, 2014). Brown et al (2014) evaluated 9 genetically different corn hybrids at IL State University for the effect of yield and nutritive value. As plant dry matter increased, the yield of starch and dry matter increased, with only a slight decline of 0.09% in NDF digestibility for each 1% increase in plant dry matter. The rankings of the nine hybrids for milk per ton changed markedly, especially when plant dry matter was less than 34%.

Influence of corn silage hybrids on DMI

Presence of leafy corn silage hybrids in dairy cattle rations often has not improved DMI over rations containing conventional corn hybrids (Kuehn et al., 1999; Bal et al., 2000b; Thomas et al., 2001; Nennich et al., 2003). However, Ballard et al. (2001) and Clark et al. (2002) reported higher DMI when feed a leafy corn silage hybrid compared to a conventional corn silage hybrid in lactating dairy cows. Ebling and Kung, Jr. (2004) compared processed conventional corn silage, processed BMR corn silage, and unprocessed corn silage on 30 mid-lactating high producing dairy cows and reported higher DMI (kg/d) for cows fed processed BMR (25.9) than processed conventional corn silage (23.4) and unprocessed BMR (24.5) being intermediate. Morrison et al. (2014) compared leafy floury corn hybrid with BMR hybrid and reported that the BMR corn silage fed cows had higher DMI than the cows fed leafy floury corn silage. Ferraretto et al. (2014b) compared leafy floury hybrid corn silage with BMR hybrid corn silage and reported higher DMI with cows fed BMR hybrid corn silage compared to cows fed leafy floury hybrid corn silage. Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to the early lactating dairy cows and reported similar DMI for both conventional and BMR corn silage. Gorniak et al. (2014) recently compared BMR corn silage with conventional corn silage to feed the lactating dairy cows at the rate of 50% of TMR on DM basis and reported higher DMI for cows fed conventional corn silage (22.5 kg/d) compared to cows fed BMR corn silage (21.5 kg/d).

Influence of corn silage hybrids on milk production

There are several lactation trials that compare different corn silage hybrids (Barriere et al., 1995; Oba and Allen, 1999a; Kuehn et al., 1999; Bal et al., 2000b; Ballard et al., 2001; Thomas et al., 2001; Clark et al., 2002; Nennich et al., 2003). However among several available hybrid types, the BMR is the only one that steadily demonstrates an enhancement in milk yield (Oba and Allen, 1999a; Bal et al., 2000b; Ballard et al., 2001). Most of the studies have reported little or no differences in milk yield when leafy corn silage hybrids were fed to lactating dairy cows (Kuehn et al., 1999; Bal et al., 2000b; Ballard et al., 2001, Nenich et al., 2003). However, studies done by Thomas et al. (2001) and Clark et al. (2002) reported significant increases in milk yield while feeding leafy corn silage hybrids compared to conventional corn silage hybrids in lactating dairy cows. Ebling and Kung, Jr. (2004) compared processed conventional corn silage, processed BMR corn silage, and unprocessed BMR corn silage on 30 mid-lactating high producing dairy cows and reported higher milk yield (kg/d) for cows fed processed BMR (44.3) than processed conventional corn silage (41.4) and unprocessed BMR (42.5) being intermediate. Yield of 3.5% FCM tended to be greater for cows fed a TMR with processed BMR compared with processed conventional corn silage. Eastridge (1999) reported 0.95 kg more milk/d when fed BMR corn silage compared to cows fed non-BMR silage, but results were inconsistent among other studies. Recent research on BMR corn silage in lactating dairy cows showed variable response with some reports of no difference when compared with conventional corn silage and some reports of improved lactational performance (Kung et al., 2008; Holt et al., 2013). Morrison et al. (2014) compared leafy floury corn hybrid with BMR hybrid and reported that the BMR corn silage fed cows produced 5.3kg more solids-corrected milk than cows fed leafy floury corn silage. Ferraretto et al. (2014b) compared leafy floury hybrid corn silage with BMR hybrid corn silage and reported higher solid corrected milk production with cows fed BMR hybrid corn silage compared to cows fed leafy floury hybrid corn silage. Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to the early lactating dairy cows and reported similar milk production between conventional and BMR corn silage fed cows. Gorniak et al. (2014) recently compared BMR corn silage with conventional corn silage to feed the lactating dairy cows at the rate of 50% of TMR on DM basis and reported similar milk yield among the treatments.

The response of milk yield to corn silage harvest at different maturities was unclear (Bal et al., 1997; Johnson et al., 2002). Corn silage processing through rollers while harvesting improved milk yield (Bal et al., 2000a; Cooke and Bernard, 2005), reduced milk yield (Dhiman et al., 2000; Ouellet et al., 2003), or produced similar amount of milk (Weiss and Wyatt, 2000; Johnson et al., 2002; Schwab et al., 2002; Johnson et al., 2003a; Ebling and Kung, 2004).

Influence of corn silage hybrids on milk components

Nennich et al. (2003) compared conventional corn silage hybrids with two leafy corn silage hybrids and reported similar butter fat percentage and milk true protein percentage across the treatment when fed to the lactating dairy cows. Ebling and Kung, Jr. (2004) compared processed conventional corn silage, processed BMR corn silage, and unprocessed corn silage on 30 mid-lactating high producing dairy cows and reported similar milk fat percentage and protein percentage among the treatments. Morrison et al. (2014) compared leafy floury corn hybrid with BMR hybrid and reported that the BMR corn silage fed cows had higher yield (kg/d) of milk fat, milk true protein and lactose compare to leafy floury corn silage.

Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to early lactating dairy cows and reported no difference in milk fat percentage, true protein percentage and lactose percentage between conventional corn silage and BMR corn silage fed cows. Gorniak et al. (2014) recently compared BMR corn silage with conventional corn silage fed lactating dairy cows at the rate of 50% of TMR on DM basis and reported higher milk fat from cows fed conventional corn silage (3.8%) compared to BMR silage (3.3%). However, milk protein percentage was similar among the treatments (3.4%). Milk urea nitrogen was significantly higher for the conventional silage (245 ppm) fed cows compared to BMR corn silage (197 ppm) fed cows. Ferraretto et al. (2015) recently compared floury leafy corn silage with BMR corn silage on lactation performance and total tract nutrient digestibility by dairy cows and reported higher milk fat percentage and MUN in cows fed floury leafy corn silage compared to cows fed BMR silage.

Influence of corn silage hybrids on nutrient digestibilities

Nennich et al. (2003) compared conventional corn silage hybrids with two leafy corn silage hybrids and reported similar starch digestibility, while feeding to lactating dairy cows. Ebling and Kung, Jr. (2004) compared processed conventional corn silage, processed BMR corn silage, and unprocessed corn silage on 30 mid-lactating high producing dairy cows and reported higher 30 h in vitro NDFD for unprocessed BMR (54%) and processed BMR (51%) compared to processed conventional corn silage (39.9%). Similarly, DMD measured by in situ techniques showed higher for both processed and unprocessed BMR corn silage (average 66.8%) by 4 percentage points compared to processed conventional corn silage. After 30 h of digestion, NDF digestion was greater in both processed and unprocessed BMR silages when compared with processed conventional corn silage (35.5% and 31.9% vs. 22.7%, respectively). Cows fed diets with both processed conventional and processed BMR silage, on average, had a greater OM (65.1% vs. 56.5%), CP (65.0% vs. 58.2%), and starch (98.9% vs. 88.5%) digestibility compared with cows fed unprocessed BMR. However, cows fed processed BMR silage had a greater ADF (39.6%) and NDF (42.1%) digestibility than cows fed either processed conventional (32.8 and 34.1%, respectively) or unprocessed BMR silage (32.1 and 30.0%, respectively) in a TMR.

The effect of processing on the digestion of fiber in corn silage has been variable. Johnson et al. (2003a) and Schwab et al. (2002) reported decreases in fiber digestion from processing; Rojas-Bourrilon et al. (1987) reported increase in fiber digestion from processing; and Ebling, and Kung, Jr. (2004), Bal et al. (2000c), and Doggett et al. (1998) reported no effect of processing on the extent of fiber digestion in corn silage. Eastridge (1999) reported that, on average, BMR corn silages had 34% less lignin and had an in situ or in vitro NDF digestibility that was 19% higher when compared with non-BMR hybrids. Morrison et al. (2014) compared leafy floury corn hybrid with BMR hybrid and reported that the BMR-fed cows had higher total tract digestibility coefficient for DM, OM, NDF, ADF, cellulose and hemicellulose. Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to the early lactating dairy cows and reported no difference in digestibilities of DM, OM, NDF and ADF between conventional and BMR corn silage. However, CP digestibility was significantly higher for cows fed conventional corn silage compared to BMR corn silage. Gorniak et al. (2014) recently compared BMR corn silage with conventional corn silage to feed the lactating dairy cows at the rate of 50% of TMR on DM basis and reported higher CP digestibility (62.5%) for cows fed conventional corn silage compared to BMR (45.5%). However, CF, NDF and ADF digestibility were greater for cows fed BMR silage compared to conventional silage.

Ferraretto et al. (2015) recently compared floury leafy corn silage with brown midrib corn silage on lactation performance and total tract nutrient digestibility by dairy cows and reported higher total tract DM, OM and starch digestibility on cows fed floury leafy corn silage compared to cows fed BMR corn silage. However, there were no differences in digestibilities of CP and NDF across the treatments.

Influence of corn silage hybrids on ruminal parameters

Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to the early lactating dairy cows and reported similar rumen pH, total VFA, acetate, propionate, butyrate and acetate: propionate ratio while fed conventional or BMR corn silage. However, Oba and Allen (2000), Taylor and Allen (2005) and Gorniak et al. (2014) recently found a reduced mean ruminal pH when feeding BMR silage compared to conventional silage.

Influence of corn silage hybrids on blood parameters

Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to the early lactating dairy cows and reported significant higher BUN, MUN and urinary urea nitrogen (UUN) in conventional corn silage fed cows compared to BMR corn silage fed cows. Gorniak et al. (2014) recently compared BMR corn silage with conventional corn silage to feed the lactating dairy cows at the rate of 50% of TMR on DM basis and reported similar NEFA concentration (mmol/L), but higher BHB concentration (mmol/L) for cows fed BMR compared to cows fed conventional silage.

Summary

Today's corn silage is not as similar as what our ancestors produced several decades ago. Several types of corn hybrids are available in the U.S. market to use as silage in the dairy cow ration including brown midrib, leafy, floury, waxy, high lysine, and high oil hybrids. Corn hybrid selection is an important management decision in silage production to feed the dairy cows as silage yield and quality can differ greatly among different hybrids. However, while selecting a corn hybrid, we need to consider both agronomical and feeding quality traits together. Lately, corn hybrids selected for silage has ever more focus on enhanced NDF digestibility additionally to high grain production and overall DM yield. Making a decision between two hybrids having high NDFD versus high starch digestibility can be challenging because of lack of research publications that directly compare between NDFD and starch digestibility. As a general rule, the higher the NDF digestibility, the higher the digestible energy will be available to produce milk while the cow can consume more forage. Starch digestibility in corn silage is very important because about 50% of its energy value is derived from the starch, which is supplied by the grain portion of whole plant corn silage. Thus, improving corn silage starch digestibility and NDF digestibility may improve production performance and decrease feed costs, especially during skyrocketing corn prices. Starch and NDF digestibility for corn-silage-based diets is affected by corn genotypes, maturity stage of corn at harvest, theoretical length of cut, and kernel processing. The effect of processing on the digestion of fiber in corn silage has been variable. Forage quality can be best predicted by the potential DMI and DMD. Innovation from recent forage quality studies and improved knowledge of how to better utilize forages in the dairy ration moved the use of forage from low to high levels in the dairy herd. The long-term potential returns from high quality high forage rations include higher levels of milk components, improved cow health, and herd profitability.

Forage blends

The historic drought throughout the United States in 2012 greatly limited the yield of forages produced (ERS, 2013). The shift in the forage area to corn and poor forage production has led to extremely low amounts of reserve forage. The small supply of forages has driven prices to historic highs and is greatly challenging the profitability of dairy operations across the United States. Many dairy farmers are looking for the possibilities and options of planting alternative forages to minimize the risk of crop failure and meet forage needs and increase harvest supplies. Annual forage crops are the number one choice in an effort to produce high biomass yield along with adequate quality. Small grains, millets, sorghums and legumes, such as forage variety soybeans and field peas, are some of the options readily available. Some of these forage crops can be integrated into a double cropping system or mixed cropping system for extra yields of forage. Corn silage is usually the higher yielding forage crop available for the dairy farmer. While corn silage is an excellent feedstuff to incorporate into the high producing dairy cow ration, it is best suited when fed with other forage sources. Corn silage is higher in starch content and lower in CP than other high quality forages. Corn silage fits best blended with high quality legumes, such as forage soybeans. Combining multiple forage species into dairy rations can be beneficial in balancing rations, as they frequently complement one another. Ration adjustments are more easily made using feed tests of single species crops rather than dealing with the variation associated with multiple species grown together. Dairy farmers across the United States are being challenged to produce or purchase adequate quantities of high quality forage to maintain milk production potential and health of the cows. Development of an economical high quality forage blend program that can be used to maintain high production levels will be critical to the success of dairy farms of the United States in the near future.

Research on major cropping systems in the United States

The cropping system refers to the combination of crops grown on a certain specified area within a specified time, usually a year. Although the term cropping system, is not new, it has been used more frequently in recent years to discuss the sustainability of agricultural production systems. Research on long term cropping systems in different regions of the United States are valuable at displaying the aggregate effects of crop management strategies on crop yields, profitability, and soil properties (Mitchell et al., 1991; Stanger et al., 2008). Different types of agriculture and cropping systems were developed throughout the universe because of variation in local climate, soil types and moisture, economics and social structure. The key determinants of the physical ability of crops to grow and using cropping system are water balance, radiation, ambient temperature and soil status (Beek and Bennema, 1972; Harwood, 1975). This is the reason why cropping systems in Asia are different than in North America. Development and adaptation of new cropping systems for specific agro-ecological situations is based on their superiority over the current cropping system in terms of their productivity and stability of production with minimal impact to the environment. Producers are making decision to adopt of new technologies based on cost involved, risk, and return from that investment. Farmers are growing multiple forage crops together to minimize risk of complete crop failures while getting multiple products to balance the daily nutrients needed by the animal along with extra income. To feed the exponentially growing population in the world, we need to intensify the current land use pattern through increasing productivity and labor utilization per unit area of available land. More forage production through intensive use of available land can be accomplished by growing different forage crops simultaneously or in succession with each other on the farm.

Benefits of multiple cropping systems under small farm conditions include lowered risk and more secure supply of food and income. Modified multiple crop systems using regular strip patterns may have potential in temperate zone farming systems in the United States. Various possibilities for these systems have been cited by Crookston (1976) and Brown and Rosenberg (1975). A number of farmers are using strip cropping in the Midwest, and reported more productive than sole cropping (Holmberg, 1985). Multiple cropping systems are predominant in many parts of the world, and alternating strips of corn and soybeans or dry beans have been used by farmers in the temperate region. Results from several experiments in Eastern and Midwest part of the United States showed considerable deviation in yield among years and locations. Corn grown in narrow strips have yielded from 10 to 40% over sole cropping, while soybeans or dry beans in narrow strips suffer yield reductions of 10 to 30% due to competition for light, water and nutrients (Francis et al., 1986).

Most long run studies on cropping system have shown the value of extended crop rotations with legume in maintaining grain yields of crops in rotation compared to annual grain production and in minimizing yearly production variability (Mitchell et al, 1991; Stanger and Lauer, 2008; Grover et al. 2009). A two year corn soybean rotation prevails on the landscape in most of the Midwest, which is consistently producing high yield of commodities for marketing and livestock feed, but depends on external application of chemical pesticides and fertilizers to amplify rotation effects (Singer and Cox, 1998; Singer et al., 2003; Liebman et al., 2008). Increasing fertilizer and pesticide costs for crop production turned farmer’s attention towards organic cropping systems recently. Organic crop/forage production has appeared as a cost-effective alternative to conventional crop production system (Greeme, 2006; Chavas et al., 2009). In Southwestern Minnesota, Porter et al. (2003) compared conventional high input two years corn-soybean rotation with organic four years oat- alfalfa-alfalfa-corn-soybean rotation and reported 7% higher corn yield and 16% higher soybean yield on high input conventional cropping system but net profit from the two systems were identical (Mahoney et al., 2004). Posner et al.

(2008) compared organic and conventional forage crop production system in southern Wisconsin and reported that yields of organic corn, soybean, and winter wheat were about 90% of high input conventional forage crop production system, no difference in forage DM yield among treatments and organic systems were more efficient than conventional systems in terms of net profit (Chavas et al., 2009). Cavigelli et al. (2008) compared conventional system (corn-winter rye-soybean-winter wheat/soybean rotation) with organic system (corn -winter rye-soybean-winter wheat hay system) in Maryland and reported 29-31% lower corn yield, 18-23% lower soybean yield in organic system compared to conventional system. Poor weed management and low soil nitrogen availability were reported as major reasons for low yield in organic system than conventional system (Cavigelli et al., 2008). Low external inputs cropping systems may improve agricultural sustainability if they are able to produce high and stable crop yields over time. Coulter et al., (2011) conducted a 16 year experiment in southwestern Minnesota to evaluate the effects of zero external input, low external input, high external input and organic input systems on crop yield and yield stability in a two years soybean-corn rotation and a four years oat-alfalfa-corn-soybean rotation and reported stable corn and soybean yield under low external input and organic input systems and more corn and soybean yield under extended crop rotations (four years) than two years.

Intercropping and mixed cropping

The simultaneous cultivation of different crops on the same piece of land has been described interchangeably as mixed cropping or intercropping in the past. However, mixed cropping and intercropping are distinguished on the basis of the pattern of the intermixture (Table 1.2). Intercropping is an alternative strategy used in multiple cropping systems, the production of two or more crops in the same piece of land. Consequently, two or more crops are managed at the same time. It has resulted in increased crop yield and profitability per unit area of land in selected crops (Sullivan, 2003). The four major types of intercropping according to spatial arrangement are row intercropping, strip intercropping, mixed intercropping and relay intercropping (Sullivan, 2003). Originally the concept of intercropping was developed a long time ago to increase food production for human beings. Intercropping system includes a main crop cultivated with one or more additional crops where the main crop is of key importance due to economic or food production reasons (Brintha and Seran, 2009).

Mixed cropping is a type of cropping system where seeds of two or more crops are mixed together and cultivated in a same piece of land at the same time (Lithourgidis et al., 2011) in the rows or broadcasted over the field. Mixed cropping is an insurance against crop failure due to abnormal weather conditions. Growing grasses in mixture with legumes in the farm or pasture conditions improved overall forage palatability and digestibility (Chaudhary and Hussain, 1985).

Advantages of intercropping

The concept of intercropping between cereals and legumes was commonly practiced because it provided both energy rich cereals and protein rich legumes to the producer/consumer, which are important from nutritional point of view and are sometimes sold for cash income (Odendo et al., 2011). Furthermore, intercropping in general provides stability of the yields over several seasons (Ofori and Stern, 1987;

Steiner, 1982), when one crop becomes unsuccessful, the other might still give a reasonable yield (Prasad and Brook, 2005; Beets, 1982; Steiner, 1982). Besides, inclusion of grain legumes also help to maintain and improve soil fertility and productivity due to the ability to fix atmospheric nitrogen with the help of symbiotic bacteria (Sanginga and Woomer, 2009; Jarenyama et al., 2000). In spite of that, the intercropping of cereal and legume may lead to decrease in yield of the legume crop because of the adverse competitive effects (Willey et al., 1983). Relay cropping and intercropping gave 59 and 80% more return per acre respectively than a sole crop of sorghum and the income increase coming mainly from higher cereal yields (Andrews, 1972).

Advantages of intercropping include increased yield, increased protein and forage quality, N contributions from legumes, greater yield stability, and reduced incidence of pests, weeds, and diseases (Anil et al., 1998). Intercropping of pigeon pea or cowpea with corn improved corn grain yield in sub-humid zones of Zimbabwe when corn is grown without mineral fertilizer on sandy soils (Waddington et al., 2007). Intercropping of corn with cowpea improved the soil moisture conservation because of increasing the light interception in the intercrops compared with the sole corn (Ghanbari et al., 2010). Corn and soybean intercrop produced more forage than sole crops (Putnam et al., 1986). Moreover, increases in crude protein content by 11- 51% were recorded for the various intercrop treatments in comparison with sole corn crop. Barley or oat with pea enhanced forage yield and quality (Carr et al., 2004). Intercropping common vetch with barley or winter wheat produced greater DM yield than sole common vetch and the intercropping of common vetch with barley at a seeding ratio 65:35 gave higher forage quality than the other tested intercrops (Lithourgidis et al., 2007). The DM yield, crude protein content, ash content, and digestibility of corn silage were increased but NDF and ADF contents were decreased when intercropping with legumes as compared to sole corn (Javanmard et al., 2009).

Major components of intercropping system

Effective intercropping requires various considerations before, during and after cultivation of crops. Growing stage of crop, crops combination, plant density, time of planting and soil status are the major components that affect success of intercropping in the future. Since vegetative growth of component crops can be influenced by intercropping (Silwana and Lucas, 2002), we have to consider the space requirement (Willey and Rao, 1981), sequence of crops and resources need. Planting pattern and selection of companion crops are the key determinants of economically successful and viable intercropping (Seran and Brinatha, 2009). Success of cereal legume intercropping largely depends on crop densities, light interception, crop types, and available soil nutrients (Francis, 1989). Selection of appropriate companion crops is largely based on the growth habit of plants, types of land, intensity of light, soil moisture and use of available soil nutrients (Brintha and Seran, 2009). Intercropping of cereals with legumes elevated the nitrogen fixation by legumes (Hardarson and Atkins, 2003) and increased the capture of growth limiting resources (Silwana and Lucas, 2002). Similarly, diverse planting time of crops help to increases efficient utilization of available resources and diminish the competition between the component crops (Andrews, 1972).

Selection of appropriate crop combination

Selection of suitable crop combination plays an important role in success of intercropping. The production potential of sole crop is limited because of competition between plants for soil nutrients, moisture, sunlight and other resources. We can reduce plant competition through spatial arrangement; however combination of crops that utilize nutrients from different soil depths and requires different intensity of sunlight might be a golden option (Fisher, 1977b). Ijoyah and Fanen (2012) studied the effects of different cropping pattern on performance of corn soybean mixture and reported that the choice of crop combination is a key to successful intercropping. In South East Asia and Africa, ground nut is usually intercropped with corn as reported by Kassam (1976). Intercropping of calopo, cow pea and green-gram with corn has minimal effect on corn yield and they were tolerant to corn shade, but popondo and mucuna reduced the corn yield while intercropping (Agboola and Fayemi, 1971). Intercropping of cereals and legumes is more frequent in Asia, Africa and South America (Vandermeer, 1972; Maluleke et al., 2005). Intercropping of corn and cowpea is more common in tropics (Van Kessel and Roskoski, 1988, Mpangane et al., 2004), but corn and bean intercropping is more practiced in Central and South America, as well as, in some parts of Africa (Singh et al., 1988). When selecting a soybean variety for intercropping with corn, those varieties that yield the highest in monocrops can be assumed to yield the highest when intercropped. Optimally higher biomass yields for later maturing soybean varieties seem to be the major factor contributing to higher protein yields in intercrops (Martin et al., 1997).

Growing stage of crop

While different crops are growing together, they should have matured in different periods of the intercropping cycle. The peak growth of one crop shouldn't coincide with the other crop when intercropping two or more crops together. In general, there is more nutrient demand for the crop during flowering and seed formation stage (reproductive phase). Selection of crops having high nutrient demands at different times (different maturity days) helps to reduce competition between the intercrops and finally helps to increase yield. Selection of crops having different maturity periods also makes harvesting and separation of grains easier. We can differentiate the periods of maximum demand to nutrient, sunlight and moisture for intercrops by selecting crops that mature at different times (Enyi, 1977) to minimize competition and maximize the yield. Intercropping of corn and green gram (*Vigna radiatat*) is a perfect match because peak light demand for corn is around 60 d after sowing while green gram is ready to harvest by that time (Reddy and Reddi, 2007). In the traditional sorghum/pigeon pea intercrop, the sorghum dominates the early stages of growth and matures in about 4 months. After harvesting of sorghum, the pigeon pea starts to flower and ripen. The slow-growing pigeon pea has nearly no effect on the grain production of sorghum (Wiley et al., 1983).

Density of growing plants

Plant population is an important factor that aids in estimating grain yield of the crops. Cultivation of two crops together in the same field during a growing season may result in inter specific competition or positive facilitation between the crops (Zhang and Li, 2003). Therefore, total mixed densities of plants and the relative proportions are important in determining yields and production efficiency of cereal-legume intercrop systems (Willey and Osiru, 1972; Lakhani, 1976). Both higher and lower plant population per unit area leads to a decline in yield (Jeyakumaran and Seran, 2007). When intercropping two or more crops, we need to adjust seeding rates to avoid overcrowding of the plants. By reducing the seeding rates, every crop gets the chance to exploit their yield potential in the available space and available nutrients. However, adjusting seeding rates of different crops is not an easy task and requires experience on agronomy and plant physiology. We can adjust seeding rates according to priority of crops. Sivaraman and Palaniappan (1996) reported that sowing of pearl millet in paired rows may offer addition space for intercropping. It is possible to get similar yields, while keeping the same plant population per unit area of the base crop by altering the orientation of the rows (Sivaraman and Palaniappan, 1996). There is no difference in yield of radish, while monocropping or intercropping with vegetable amaranths and keeping the radish plant density constant (Brintha and Seran, 2009). Increasing plant population from 6 to 10 plants per meter square of lablab bean plant (*Lablab purpureus*) caused a decrease in DM of corn (Maluleke et al., 2005). Increased plant density reduced the number of leaves in corn-okra intercropping because of competition for light and other nutrients (Muoneke and Asiegbu, 1997). Prashaanth et al. (2009) also reported decreased leaves number while intercropping eggplant (*Solanum melongena*) and groundnut (*Arachis hypogaea*).

Planting/sowing time

The relative time of planting a component crop is a vital management variable manipulated in intercropping of cereal and legume. Planting time also affects yield of intercrops. Most of the time intercrops are sown at the same times, but harvest at different time. Mongi et al. (1976) reported higher yields when cowpeas were planted at the same time with corn. Late planting of sweet potato (*Ipomoea batatas*) adversely affected corn yield, but no effect on corn yield when corn and sweet potato were planted simultaneously (Amede and Nigatu, 2001).

Variation in planting times improves overall productivity and reduces competition of growth limiting resources in intercropping (Andrews, 1972). Planting component crops at altered times allows for the maximum utilization of available resources, since crops cover the soil throughout the growing season (Willey, 1979). Francis et al. (1976) reported that planting corn and beans 5 to 15 d apart decreased yield of the intercrop compared to mono crops. Corn planted 5 to 15 d ahead of beans increased corn yields by 13 to 43%, but the associated bean yields were decreased by 20 to 27% compared to simultaneous planting of corn and beans. Average land equivalent ratio (LER) was 39% higher when beans were planted 5 to 15 d earlier than corn. Francis et al. (1982) studied intercropping of corn with four contrasting beans varieties planted 5 to 10 d interval and reported that near-simultaneous sowing of component crops is optimal to attain the highest combined yields and LER. Adjusting the time intervals between growth durations of component crops affected the efficiency of cereal-legume intercrop systems. When intercropping 85 d bean and 120 d corn, a yield advantage of 20% was lowered by planting beans 28 d after corn (Osiru and Willey, 1976). A yield advantage of 32% entirely wiped out when green gram was planted 7 d after bulrush millet (May,1982).

Spatial arrangement

There are four major types of spatial arrangements used in intercropping. However most practical systems currently in used are modified versions of those four major types (Grossman and Quarles, 1993). Row intercropping refers to growing two or more crops at the same time with at least one crop planted in rows. Strip intercropping refers to growing two or more crops together in strips wide enough to permit separate crop production using machines, but close enough for the crops to interact. Mixed intercropping refers to growing two or more crops together in no distinct row arrangement. Relay intercropping refers to planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting (Sulivan, 2003). Row intercropping of vetch at 50% seeding rate has reported to more advantages in terms of yield than corn-lablab intercropping (Bekele et al., 2013).

Mohta and De (1980) and Oseni and Aliya (2010) suggested that compare to arrangement of component crops within rows, row management may also affect the overall efficiency of an intercropping system. Evans (1960) reported LERs of 1.09 in the same row arrangement compared to 1.30 in alternate rows and 1.38 in a hill arrangement of intercropping with corn and groundnut. On the other hand, Agboola and Fayeni (1971) reported similar performance when corn and cowpea were planted in the same or alternate rows. Mohta and De (1980) conducted research trials on intercropping of corn-soybean and sorghum-soybean and reported similar yields of the cereals when intercropping with soybean either in single or double alternate rows. In corn-soybean intercropping, 31% and 25% more yield of soybean was reported when components crop were arranged in double alternate row and single alternate row, respectively.

Intercropping of corn and soybean for forage production

Corn and soybean intercropping is a viable option to produce higher yields and quality silage compared to monocropping corn. The major benefits of the corn-soybean intercropping is that the CP content of the silage will increase with the addition of soybeans, which eventually affect the overall quality of the silage (Ahmed and Rao 1982; Herbert et al. 1984; Toniolo et al. 1987; Martin et al. 1990). The intercropping of corn-soybean for quality silage production may prove to be a more environmentally sustainable way of producing silage compared to monocropping of corn, although this practice is not common in the Midwest region of the United States. Growing corn and soybean with narrow row spacing using an intercropping system would prevent soil erosion more effectively compared to monocropping. Martin et al. (1991a) reported that narrower row spacing had no antagonistic effect on the yields of component crops when intercropping corn and soybean with 20 cm and 40 cm row spacing. Corn and soybean intercropping system benefited the corn from associated soybean because of transfer of N from the legume to the corn (Martin et al. 1991b).

Appropriate variety selection of a legume is vital for the overall success of the intercropping. Early legume varieties will have set seeds and their leaves will be senescing by the time the corn is at its optimum stage for ensiling. Preliminary studies on the mechanical harvesting of early soybean varieties intercropped with corn for silage have shown substantial losses of soybean seeds due to pod shattering (Martin et al., 1997). Since most of the protein in the soybean plant will have been translocated to the seeds at harvest, the pod shattered soybean silage would not have the expected higher CP content.

Addo-Quaye et al. (2011) compared the corn-soybean intercropping system and indicated that the relative time of planting and spatial arrangement are important factors determining the overall productivity of the corn-soybean intercropping system. They further mentioned that the component crops must be sown simultaneously to obtain adequate yields of both crops. For corn spatial arrangement of single rows of corn alternating with single rows of soybean gave the best yields where as a spatial arrangement of single rows of maize alternating with double rows of soybean yielded the best with respect to soybean. Land equivalent ratio (LER) values observed greater than unity implying that it will be more productive to intercrop corn and soybean than sole crop.

Metwally et al. (2009) studied the effect of 3 intercropping systems of corn and soybean and two corn cultivars on yield, yield components and LER and reported that solid planting of corn had significant increases in each of leaf area, dry weight and grain yields per plant. Solid plantings of corn and soybean gave higher yields than intercropping patterns. The highest yield of intercropped corn grains per feddan (1 Feddan = 0.42 ha) was obtained from alternating ridges (2:2); whereas, mixed intercropping system gave highest yield of intercropped soybean than others. The LER was higher in intercropped plantings than solid ones ranged from 1.13 to 1.46. Also, mixed intercropping pattern had higher LER value than alternating ridges. The intercropping systems were more cost-effective than solid plantings. Alternating ridges 2:2 gave the highest values of net return than other intercropping patterns.

In an intercropping system, corn and soybean had a complementary competition mode against each other that is the advantage of intercropping than the pure cultures of two species. Martin et al. (1997) studied the effect of soybean variety on corn-soybean intercrop biomass and CP yields and reported higher biomass and CP yields for late soybean varieties than early soybean varieties under both monocropping and intercropping systems. In contrast to the sole corn, intercrops with all soybean varieties yielded higher CP content. Under intercropping, only the late varieties of soybean produced significantly higher CP yields than the sole corn. On the other hand, none of the soybean varieties resulted in significantly lower biomass yields compared to the sole corn. With the late soybean variety, LER of the intercrop shoot biomass yield and the intercrop shoot protein yield showed yield advantages of intercrops over sole crops of 21% and 10%, respectively. The late soybean variety resulted in an increased intercrop shoot protein content without reducing the intercrop shoot biomass yield, because it was still green enough to be harvested with minimal pod shattering.

Clement et al (1992) studied intercropping of corn and soybean and reported higher corn and soybean yield in 2:1 and 3:2 row arrangements of corn and soybean. Sharaiha and Hattar (1993) studied the effect of intercropping and litter on the yield of corn, soybean and watermelon in single and mixed planting and reported higher yield when corn was blended with soybean by 45 to 65%. But, higher yield of soybean was achieved in corn-soy blend with 35 and 34% depending on the year of test. Nabavi and

Mazaheri (1998) reported maximum LER when corn and soybean were intercropped at seeding ratio of 25:75 respectively. A review on assessment of different treatments using LER revealed that corn intercropping at a density of 5.3 plants/m^2 with a density of 42 soybean plants/m^2 had the highest biological efficiency (Pirzad et al., 2002). Egli and Bruening (2000) studied the potential of early maturing soybean cultivars in late planting and reported decline in grain yield with subsequent delay in planting compare to the optimum planting date. Rahimi et al (2002) studied the corn and soybean intercropping and reported higher corn yield at 50:50 and 25:75 blend of corn and soybean ratio. However, higher soybean yield was observed in monoculture of soybean.

Amjadian et al. (2013) studied the effect of planting dates on intercropping of corn and soybean and reported that intercropping increased overall yield and yield components including the number of pods per plant, the number of seeds per pod, grain weight, seed yield, and number of seeds per corn cob in all planting dates, except very late planting compared to the monocropping.

Effects of intercropping on forage seed production

Most of the time, the cereal crops with relatively faster growth rate, greater height and more extensive roots provided more favor in competition with legume crop. As a result, more yield loss of the minor crop is mainly because of reduced photosynthetically active radiation reaching the lower parts of the intercrop canopy, occupied by the minor legume (Liu et al., 2010). The quality and intensity of sunlight intercepted by the canopy are key determinants of production components and therefore seed yield of soybean since soybean is very sensitive to shade (Liu et al., 2010; Purcell, 2000). Levels of sunlight during the late flowering to mid pod formation stages have been reported to be more serious than vegetative and late reproductive periods (Liu et al., 2010; Schou et al., 1978). Matusso et al. (2014) concluded that the corn-soybean intercropping pattern has significant effect on production of corn stover and grain. Corn and soybean intercropped at 2:2 ratio produced significantly higher stover and grain yields of corn compared to sole or other ratio. Similarly, soybean yield was reduced by 52 to 81% in two different growing seasons. Chang and Shibles (1985) reported that the level of the corn population generally enforced a limit on the yield of the intercrop cowpea and that there was no effect of increasing cowpea density. Intercropping considerably reduced the final stand count of corn by 3.2% and that of the legumes by 10.6% compared to the sole crops (Bekele et al., 2013).

Corn intercropped with vetch had a significantly higher 1000 kernel weight than the one intercropped with lablab bean. This difference may have most likely occurred due to the differences in the growth habits of the two legume species. In addition, less light interception to the crop canopy and lower photosynthetic efficiency might have resulted in lower 1000 kernels weight of corn intercropped with lablab bean (Bekele et al., 2013). Grain yield and growth of legume component declined significantly when intercropped with high densities of the cereal component in a corn-bean intercrop system. Increasing plant density of corn by 3 fold, from 18,000 to 55,000 plants/ha caused a drop in leaf area index by 24% and grain yield of bean by 70% (Gardiner and Craker, 1981). Fisher (1977a) conducted research on corn-bean intercropping at different densities (13,700, 27,000 and 47,700 plants/ha of corn combined with 23,300, 56,300 and 121,000 plants/ha of beans, respectively, designated as low, medium, and high densities), for each density, the yield of intercrop corn was similar with monocropping corn. But, intercrop bean yield was significantly improved with a rise in bean density. Strip-intercropping soybean with corn decreases yields in soybean border rows. Separating corn and soybean with a small grain strip could decrease competition for soybean and improve overall yield (Iragavarapu and Randall, 1996).

Effects of intercropping on forage blend biomass yield

Any modifications to an intercropping systems that help minor crops (legumes) to assure exposure with increased sunlight, the minor crop has the potential to increase the yield and increase overall productivity of the intercropping system (Mashingaidze, 2004). Woomer and Tungani (2003) stated that intercropping of 2 × 2 rows of corn and soybean under the MBILI system (alternating two rows of corn and then two rows of the legume) resulted in 20% more light to the soybean when compared to the conventional intercropping pattern. Ennin et al. (2002) stated that 4% more sunlight was received by crops in closer row arrangements of soybean and corn than in equally spaced 2 rows soybean: 2 rows corn. Then again, due to adverse competitive effects between the crops, intercropping can lead to a decline in yield of one or more of component crops (Willey et al., 1980). An intensive review paper published on intercropping by Ofori and Stern (1987) showed that on an average legume yield decreased by 52% of the mono crop yield, whereas the cereal yield was decreased by only 11% of mono crop yield. The highest dry biomass of the forage and the highest forage crude protein yield was obtained from row intercropped vetch at 50% of the recommended seed rate with corn compared to row intercropped or broadcasted lalab and broadcasted vetch (Bekele et al., 2013).

Effects of intercropping on forage nutritional quality

Soybean has been successfully intercropped with different cereals including corn, oat, barley, sorghum and wheat (Anil et al., 1998) and other crops like cassava and cow pea (Quainoo et al., 2000; Li et al., 2001; Chabi- Olaye et al., 2005). Forage production from corn and soybean intercropping was comparable with that from corn monocropping (Sheaffer et al., 2001). When corn growth is limited and poorly established, soybean is able to establish well and produce yields equivalent to those of monocrop soybean (Carruthers et al., 2000). Compare to monocropping systems, intercropping has multiple advantages including improved DM yield and CP concentration. Intercropping of corn and soybean improved CP concentration by 11 to 15% (Putnam et al., 1986; Toniolo et al., 1987; Carruthers et al., 2000) compare to monocrop corn. Smith and Kallenbach (2006) reported increased CP of mixed crop up to more than 17%, NDF reduced to 56% and ADF reduced to 23% when soybean was intercropped with ryegrass or cereal rye. Lower stem NDF concentration of intercrops sorghum and soybean (64.5%) compared to monocrop soybean (68.1%) and 3.3% higher in vitro DMD for intercropped compare to monocropped soybean were reported by Redfearn et al. (1999).

The highest forage crude protein yield was obtained from row intercropped vetch at 50% of the recommended seed rate with corn compared to row intercropped or broadcasted lalab bean and broadcasted vetch (Bekele et al., 2013). Intercropping of corn with legumes significantly enhanced corn stover CP content, CP yield and total fodder CP yield by 20, 18 and 39%, respectively as compared to the sole cropping of corn (Bekele et al., 2013).

Effects of ensiling duration on nutritional quality of silage

Corn silage has been extensively used as a major component of rations for ruminants in many parts of the world because of its palatability, high energy concentration, relatively constant feed quality and storability (Khan et al., 2015). The principal goal of ensiling forages has been to preserve the maximum amount of original dry matter, nutrients and energy in the crop for feeding at a later time. Production of quality corn silage is possible with a good microbial fermentation process that reduced the pH rapidly within a few weeks with nominal loss of DDM (Oude Elferink et al., 2000). Once the pH is around 4.0, the silage is stable for a long period, until the silo is opened for feeding and exposed to air (Pahlow et al., 2003). On the other hand, there are some evidences that some microbial activity also occurs during the stable phase of the ensiling process (Der Bedrosian et al., 2012). Because of the microbial activity during the first 2 to 6 weeks and the possible ongoing microbial activity afterwards, ensiling duration may affect the final nutritional quality of the silage (Ali et al., 2015).

With skyrocketing corn grain prices, many dairy farmers are interested to increase the proportion of corn silage in their dairy cow ration. Newbold et al. (2006) analyzed 15 corn silage samples from a commercial dairy farm every 15 d for 2 to 10 months after ensiling and reported that 3 h in situ starch degradability increased with ensiling time and correlated with corn silage DM content at ensiling. Mean 3 h in situ starch digestibility was 53.2% at 60 d and 69% at 300 d after ensiling. Crude protein degradation increased with storage time, but was not correlated with starch digestibility. In situ dry matter digestibility and rumen degradable protein of high-moisture corn increased with time of ensiling (Benton et al., 2004). Time after ensiling of corn silage may be important to consider for diet formulation because of changes in digestibility of different nutrients. Diet adaptations, such as adjusting starch level on TMR, could be done when starch digestibility improves in order to prevent acidosis.

Both ensiling temperature and ensiling duration play an important role in the rumen degradation of corn silage (Ali et al., 2015). Ward and de Ondarza (2008) studied the effect of month of sample submittal on corn silage nutrient fractions and fermentation profiles and reported that lactic acid, pH, titrable acidity, and soluble protein didn't reach maximum levels until 4 months after ensiling. Thus, at least 4 months are essential for full fermentation of corn silage. Ninety days ensiling of corn stover treated with 4% molasses and 20% water showed good color, smell, softness, nutritional quality and longer preservation capacity compared to 45 d ensiling (Bostami et al., 2008). Previously many studies have been focused on establishing the optimal ensiling conditions, including days at harvest (Mayombo et al., 1993; Hartmann et al., 2000), DM at harvest (Yahaya et al., 2002), genotype (Schwarz et al., 1996; Argillier & Barriere, 1996; Johnson et al., 2003a), weather while growing (Meisser & Wyss, 1998), breeding strategies (Barriere et al., 1997; Bavec and Bavec, 2002), and quality of ensiled plants (Stockdale & Beavis, 1994; Johnson et al., 2003a). Additives like molasses, organic acids (Jaakkola et al., 2006) and bacterial inoculants were used in past to get a rapid anaerobic fermentation to quickly drop the pH of ensiled materials. Bacterial inoculants were also used to increase aerobic stability once the silo was opened to feed the cows (Weinberg et al., 2002; Muck, 2004). Limited number of studies has been done in the past that describes the effect of the length of the ensiling period on the quality of the silage (Lee et al., 2002; Yahaya et al., 2002; Bostami et al., 2008; Ward and de Ondarza, 2008). Recently, Ferraretto et al. (2015) reported that the extended time in storage increased the ammonia-N content, soluble CP content, and in vitro starch digestibility in whole plant corn silage of various hybrids, maturities, and chop lengths.

Fermentation of ensiled corn silage by lactic acid bacteria usually ends within three weeks of ensiling (Jaster, 1995). On the other hand, a study done by Ward and de Ondarza (2008) suggested that corn silage requires at least four months to complete the fermentation. Kleinschmit and Kung (2006) reported that a satisfactory fermentation of corn silage in mini silos required 361 d of ensiling, where the major increase in acetic acid in untreated corn silage occurred between 282 and 361 d. At anaerobic and low pH condition, *Lactobacillus buchneri* is able to convert lactic acid to acetic acid, ethanol and 1, 2 propanediol (Oude-Elferink et al., 2001). This organism is relatively acid tolerant and can survive for long periods of time in fermented silage (Schmidt et al., 2009). Yahaya et al. (2002) also reported that increasing ensiling time of high moisture orchard grass would result in the excessive losses of DM, water soluble carbohydrate, hemicellulose and cellulose in the silage.

Summary

Various types of agricultural cropping systems were developed worldwide because of variation in local climate, soil types and moisture, economics and social structure. The simultaneous cultivation of different crops on the same piece of land has been described interchangeably as mixed cropping or intercropping in the past. However, mixed cropping and intercropping are distinguished on the basis of the pattern of the intermixture. Advantages of intercropping include the increased yield, increased protein and forage quality, N contributions from legumes, greater yield stability, and reduced incidence of pests, weeds, and diseases. Growing stage of crop, crops combination, plant density, time of planting, spatial arrangements and soil status are the major components that will affect the success of intercropping in the future. Corn and soybean intercropping is a viable option to produce higher yields and quality silage compared solely to corn for silage. The major benefit of the corn-soybean intercropping is that the CP content of the silage will increase with the addition of soybean, which eventually affects the overall quality of the silage. In an intercropping system, corn and soybean have a complementary competition mode against each other that is the advantage of intercropping than pure cultures of two species.

Corn silage has been extensively used as major components of rations for ruminants in many parts of the world because of its palatability, high energy concentration, relatively constant feed quality and storability. Previously many studies have been conducted to establish the optimal ensiling conditions including days at harvest, DM at harvest, genotype, weather, while growing, breeding strategies, and quality of ensiled plants materials. The principal goal of ensiling forages has been to preserve the maximum amount of the original dry matter, nutrients and energy in the crop for feeding at a later time. Production of quality corn silage is possible with a good microbial fermentation process that reduced the pH rapidly within a few weeks with nominal loss of DDM.

Conclusions and implications

Water is the most essential nutrient for dairy cattle, but providing clean safe water is often overlooked. However, good quality water is considered an inadequate commodity in many parts of the United States, as well as, other parts of the world. Water quality can affect the rate of water consumption and water consumption is closely related to DMI in both dairy and beef cattle. Thus, it is very important to supply quality water to dairy cattle to maintain growth and milk production. Sources of water contamination can also affect animal production performance as well as wellness. Poor water quality can lead to poor performance and poor reproduction that often goes unnoticed, but that can be deadly as well. Drinking water quality should be part of an evaluation when there is a problem with poor cattle performance. The only way to know if a problem exists is to test the water for anti-quality factors. During a drought, water quality declines as the concentration of pollutants increases when water evaporates and becomes stagnant. Lack of controlled research studies makes it difficult to evaluate the importance of water quality in dairy herds. Some dairy nutritionists don’t care about mineral content of water while formulating the ration because of a belief that they are not biologically available to cows. However in some cases, minerals in water are more biologically available for cows compared to feeds. The digestibility of feeds can also be predicted by in vitro techniques, which simulate the digestion process as in live animal. Rumen fermentation by anaerobic microbes results in production of VFA, CO_2, CH_4 and microbial mass. The amount of gas produced is proportional to acid production, thereby serving as an indicator of VFAs produced by fermentation. The amount of gas produced during incubation is measured to predict the extent and rate of feed digestion. In vitro gas production systems have successfully been used to determine organic matter, DM and NDF digestibility, energy value of TMR, kinetics of fermentation, anti-nutritive factors, rumen modifiers, feed associative effects, rumen microbial change, nutrient synchronization, and environmental degradation, etc. Some commercial laboratories offer in vitro feed digestibility which can be used in new ration-evaluation computer models with the goal of optimizing nutrient utilization, animal performance and minimize nutrient excretion to protect the environment. However, dairy producers are not able to produce the same amount of milk from the cow as estimated by the computer model using the data from in vitro gas fermentation system. Since, there is a big gap between estimation and real production, there could be some hidden factors affecting the efficiency of predictability of an in vitro gas fermentation system. Currently, our in vitro gas fermentation system is using distilled water to make buffer which is not the real farm water source offered to the cow. Real water offered to the cows may affect gas fermentation and nutrient digestibility because of its minerals content and microbes. Thus, use of real farm water instead of the distilled water in in vitro gas production system may precisely estimate the digestibility of nutrients, gas production and finally milk producing ability of the ration.

The level to which forage has the capacity to produce a desired animal performance is called forage quality. The better the quality of forage, the higher will be the DMI, more milk will be produced with higher level of milk content, and the less need to supplement. However, forage quality fluctuates greatly between and within forage crops, and nutritional needs vary between and within animal species and classes. Quality forage production program for a given situation requires familiarity with the factors that affect forage quality, then exercising management accordingly. Analyzing forages for nutrient content can be used to determine whether quality is adequate and to guide proper ration supplementation. Forage quality can impact dairy farmers through their effects on milk yield, feed costs and wellness of dairy cows. Low quality forages are usually consumed slower and in lesser amounts compared to high quality forages, which provides lesser nutrients to the dairy cows to produce milk. Corn silage is a principal feed component in many rations fed to dairy cows, and its use continues to increase in high producing lactating dairy cow rations. Numerous kinds of corn hybrids are available in the U.S. market to produce corn silage for dairy cow rations including brown midrib, leafy, floury, waxy, high lysine, and high oil hybrids. Lately, corn hybrids selection for silage has focused more on enhanced NDF digestibility, in addition to high grain production and overall DM yield. Corn hybrid selection is an important management decision in silage production to feed the dairy cows as silage yield and quality can differ greatly among different hybrids. Although past research has not shown a steady increase in milk production or DMI from feeding a particular corn silage hybrid, improved corn silage hybrids are introduced to the marketplace every year. With release of new corn hybrids, it is essential to evaluate their agronomic traits, as well as, their response on dairy cattle performance.

Development and adaptation of new cropping systems for specific agro-ecological situation are based on their superiority over the current cropping system in terms of their productivity and stability of production with minimal impact to the environment. Producers are making decisions to adopt new technology based on costs involved, risk, and return from that investment. Farmers are growing multiple forage crops together to minimize risk of complete crop failures and to obtain multiple products to balance the daily nutrients need of animal along with extra income. To feed the exponentially growing population in the world, we need to intensify the current land use pattern through increasing productivity and labor utilization per unit area of available land. More forage production through intensive use of available land can be accomplished by growing different forage crops simultaneously or in succession with each other. The relative proportion of corn seed is an important factor concerning yield, quality and production efficiency of a corn-soybean used in a mixed cropping or intercropping to produce a corn-soybean forage blend. In general, two methods are used for the seeding proportion in mixed cropping or intercropping including the replacement and additive ones of soybean or corn seed. Forage blends produced through intercropping or mixed cropping of corn and soybean have the potential to increase forage yield through N contribution from soybeans, as well as, improve forage quality through increased CP content, mineral content and fiber digestibility. Although, most of the forage blend research showed increase biomass production and CP content of the forage, there is wide range in productivity and CP content of the forage because of the variation use in the proportion of corn and soybean seeds. Dairy forage producers are looking for the appropriate proportion of corn and soybean seeds for intercropping or mixed cropping to optimize yield, as well, as nutrients composition of forage blends to feed the high producing dairy cow.

Table 1.1. Brief overview on water treatment methods[1]

Treatment Methods	Working principle	Removing substances	Possible issues
Activated carbon filtration	While water flow through filter, contaminants absorb or stick	Pesticides, odors, bacterial iron, heavy metals, cryptosporidium, Giardia	Carbon cartridges should be replace regularly
Reverse osmosis	Contaminants removed by forcing water through membrane with microscopic holes	Some pesticides, Fe, Pb, Cu and other heaving metals (As), Cryptosporidium, viruses	Membrane should be regularly monitored, can waste large amount of water,
Ion exchange water softening	Ca and Mg in water exchanged for Na or K	Ca, Mg, dissolved Fe and Mn, Cd, Cu and Zn	Need to recharge softener resin bed, increased Na and K content of water
Sediment filtration	Sand filter trap sand, soil or other particles in water	Sediment, turbidity	Cartridge replacement or backwashing must be done regularly
Distillation	Water heated to produce steam which is then	Sediment, salt, TDS, pesticides, heavy metals, bacteria	High energy cost, scale build up, bland taste water

	condensed		
Aeration	Oxygen introduced to water by aerator	Dissolved Fe and Mn, methane odor, H_2S gas, radon	Regular backwashing of filter, not recommended for bacterial water
De-aeration	Mix air with water to remove dissolved gases from water	Dissolved H_2S gas, methane gas odor, radon	High hard water cause scale build up
Continuous chlorination	Cl injected into water to kill bacteria and treat Fe and Mn	Dissolved Fe and Mn, HS gas odor, kill most of microbes, Giardia, viruses	Needs adequate contact time, toxic if overdose, formation of trihalomethane, regular change of filters
Ultraviolet radiation	UV light kills bacteria and other microbes	Bacteria, Giardia, Viruses	Sediment buildup, algae growth, clean lamp regularly
Ozonation	Ozone mixed with water and kill most microbial pathogen, oxidize Fe and Mn	Bacteria, Giardia, Viruses, Cryptosporidium, dissolved Fe and Mn	Costlier, toxic gas, need to buy test equipment, dehumidification of surrounding air is required
Ultra, micro, and nano filtration	Suspended particles are trapped on filter	Cryptosporidium, Giardia, Viruses	Cartridge replacement or backwashing

[1] Adapted from Dvorak and Skipton, 2008

Table 1.2. Differences between mixed cropping and intercropping

Mixed cropping	Intercropping
Seeds of different crops mixed together before planting.	Seeds of crops are not mixed together before planting.
Either sown in rows or broadcasted over field.	Usually have set patterns of rows for component crops.
Fertilizer, herbicide application and pest control to individual crop is difficult.	Fertilizer, herbicide application and pest control to individual crop is possible.
Not possible to harvest and thresh individual crop separately.	Possible to harvest and thresh individual crop separately.
Only selling of mixed produce is possible.	Selling of each produce is possible.
Aim is to minimize risk of completer crop failure.	Aim is to increase productivity per unit of land (LER).
All crops are given equal priority and care.	More emphasis is given to the main crop.
Main objective is to get at least one crop under favorable condition.	Main objective is to utilize space between two rows of main crop.
Direct competition between crops for light and nutrients.	No direct competition between crops for light and nutrients.
Same planting time for all crops.	Planting time may be same or different.

CHAPTER 2

THE INFLUENCE OF SOURCE AND QUALITY OF WATER AND A WATER TREATEMENT SYSTEM ON THE RUMINAL FERMENTATION AND NUTRIENT DIGESITBILITY OF A TOTAL MIXED RATION USING AN IN VITRO GAS PRODUCTION MEASUREMENT SYTEM

ABSTRACT

This study was conducted to evaluate the water source and treatment system on rate of ruminal fermentation and nutrient digestibility. One g of dried ground standard total mixed ration (TMR) was placed in a 50 μm dacron bag, heat sealed, and then placed in a 500 mL Ankom Gas Fermentation Bottle (GFB) to measure the rate of digestion. Treatments were: Control (DW): laboratory distilled water; FU: untreated water from a local SD dairy farm; FT: dairy farm water treated with H_2O_2 product; and MW: Municipal water used at SDSU dairy farm treated through lime softening and gas chlorination. Treatments were replicated 4 times as individual GFB and study was conducted in 4 blocks. Rumen fluid was collected from a ruminally cannulated cow fed the same TMR and strained through 4 layers of cheesecloth. Fifty mL of rumen fluid mixed with 200 mL of buffer prepared from each of the water treatments were added to the GFB and incubated in a circulating water bath at 39°C. Gas measurements were collected every 5 min for 30 h. After 30 h fermentations, dacron bags were removed, rinsed, and dried. The rate of gas production was greater ($P < 0.01$) for DW compared to other treatments (16.40, 9.50, 9.66 and 9.71%/h for DW, FU, FT, and MW, respectively). Ammonia production (mg/dL) was lower ($P < 0.05$) in DW compared to FU and MW.

Total volatile fatty acids (mM/L) and acetate production was lower in DW compared to MW. The dry matter digestibility (81.99, 81.61, 80.82 and 81.61% for DW, FU, FT, and MW, respectively) tended to be lower ($P < 0.09$) for FT water compared to DW water, with all other treatments being intermediate and similar ($P > 0.10$). The digestibility of neutral detergent fiber was similar ($P > 0.10$) for all treatments. Water source and quality can affect rate of ruminal fermentation. Thus, use of real farm water being offered to the cow to conduct in vitro gas production measurements may accurately predict the ruminal fermentation, digestibility and total gas production compared to laboratory distilled water.

Key words: gas production, in vitro, water quality

INTRODUCTION

Water source and quality are becoming greater concerns for dairy farmers as they continue to grow their operation, which is creating additional stress on water resources. Drawing greater water volumes, weather patterns, fertilizer application to crops, insecticides and pesticides can be factors that might affect water quality within a water source. Water is a vital nutrient and plays a pivotal role in milk production (Mann et al., 2013), but water is often a forgotten and overlooked nutrient in livestock production. Water quality is not well understood as to the impact on livestock production and performance. Too often dairy producers and their consultants have insufficient understanding of water nutrition of dairy cattle. Having an excellent working knowledge about provision of this most important essential nutrient is crucial for optimum performance of dairy cattle and the financial success of dairy businesses (Beede, 2006).

Very limited information exists in the literature on water quality influencing dairy production and that information relates specifically to toxicity. Casper et. al. (2010) and Socha et al. (2001) have summarized water quality on livestock operations, but these data have never been published in full length articles. In addition, little to no information exists on water quality and composition influencing the nutritional performance of lactating dairy cows. Casper et al. (2001) reported that water intake and quality could have as much as a 25% change in the dietary cation anion difference when feeding transition dairy cows. The hypothesis is that water quality can have substantial impacts on productivity. Much of the SD water available and other parts of the U.S., are not sufficient in quality to sustain optimal performance and health of dairy cattle (Casper et al., 2012). For example, water high in salt (Na and Cl) content has negative impacts on production and health of dairy cattle. Thus, water quality can have an impact on the nutritional performance, as well as, the occurrence of metabolic problems that might occur at calving (Schauff et al., 2000).

Since, water quality at a dairy farm is a dynamic component of the operation; it should be evaluated using the same methods as forage quality. Water samples should be analyzed periodically and records maintained on the farm. Although, there are several water treatment systems available in the market to improve water quality, their impacts on water quality and the biology (ruminal fermentation, VFAs production, ammonia production, digestion and absorption) of dairy cattle production are not well known. No literature is currently available that evaluates water treatment systems (carbon filtration, air stripping, chlorination, distillation, cation-anion exchange filtration, reverse osmosis, hydrogen peroxide etc.) on ruminal fermentation and nutrient digestibility of dairy cattle fed a total mixed ration. Thus, it is crucial to know how water sources, qualities and treatment systems may affect rumen biology and ultimately milk production by dairy cows.

It is important to determine the effects of water quality on animal performance so that appropriate management practices can be developed. The purpose of this study was to determine efficacy of different water sources and a treatment system using an in vitro ruminal fermentation gas production system. This system measures the rate of gas production by simulating the rumen, which directly correlates with ruminal microbial digestion and growth. In addition, the system will provide direct measurements of ruminal pH, VFA, NH_3-N, DMD, and NDFD of the TMR. We hypothesized that there will be differences in nutrients digestion, gas production and ruminal fermentation patterns among water sources because of differences in mineral contents of water used to prepare buffer.

OBJECTIVES

The objective of this study was to compare effect of distilled water buffer (conventional method) and real farm water buffers used in in vitro gas production measurement system on nutrient digestion, gas production and ruminal characteristics.

MATERIALS AND METHODS

Experimental plan

Four different sources of water were selected to make buffer evaluated in the in vitro gas production measurement system. The treatments were:

B: Blank: laboratory distilled water, but no TMR incubation for correction of back ground gas production.

DW: Control: Laboratory distilled water, but TMR incubated as C.

FU: Local dairy farm untreated water prior to the H_2O_2 injection system.

FT: Local dairy Farm treated water using a H_2O_2 injection system.

MW: Dairy research and training facility, which is municipal rural water supply treated through lime softening and gas chlorination.

Each treatment was replicated in 4 gas fermentation bottles and the whole treatment block was replicated 4 times for a total of 16 observations per treatment.

Preparation of sample feed

The TMR was formulated to meet the nutrient requirement of a high producing lactating dairy cow based on National Research Council (2001) nutrient requirements of dairy cattle and consisted of alfalfa hay (25% of DM), corn silage (25% of DM), and concentrate supplements (50% of DM). This ration was being fed to the dairy cows at the SDSU dairy research and training facility (DRTF). The TMR sample was dried at

55^{o}C for 48 h in force air oven and ground through a 1mm screen of a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA). Approximately 1 g of TMR was accurately weighed and placed in a nylon dacron bag having a 57 µm pore size (ANKOM, Macedon, NY) and heat sealed. A blank sealed Dacron bag was incubated as well to correct for blanks.

Preparation of buffer solution

The four different water sources were used to prepare the treatment buffers and reducing solution (Mould's buffer: Reference procedure 080221) that are required for the in vitro digestion system. Mould's buffer was prepared according to lists, weight and sequence of specific chemicals (Table 2.1). Reducing solution (Table 2.2) was added once buffer reached 100^{o}C. Typically, using this system, the feed sources are changed for evaluation, but in this project the water source is changed (treatment) for preparation of buffer solution. Once prepared, buffer was incubated for 12 h at 39^{o}C just before use.

Preparation of inoculum

Rumen fluid was collected from a ruminally cannulated high producing lactating dairy cow fed the same TMR being using as the feed in this experiment. Rumen fluid was collected 3 h after feeding the cow into a pre-warmed thermos, CO_2 flushed, and transported to the laboratory where rumen fluid was blended under CO_2 for 30 sec and then strained through four layers of cheesecloth into a preheated CO_2 flushed flask.

Preparation of ANKOM Gas production system and working sample

The recently developed Ankom innovative gas production system (Ankom Technology®, Macedon, NY, USA) consists of a gas fermentation bottle equipped with a pressure detector connected wirelessly to a computer (Figure 2.1). Pressure values are recorded at preset intervals and transmitted to the PC as gas accumulates in the headspace. When a preset threshold pressure has been reached, the pressure is automatically released after measurement to prevent negative feedback inhibition on ruminal microbial growth. The use of feed sealed in nylon bags leads to additional measurements of nutrient degradability.

Each 500 mL bottle was pre-warmed (39^{o}C) with 200 mL of the respective buffer, nylon bag with feed sample, and 50 mL prepared rumen fluid added under continuous purging with CO_2 for 1.5 min. Rumen fluid at 0 h was collected for VFAs, ammonia, and pH measurements. Subsequently, the bottles were connected to a module and incubated in a circulating water bath at 39^{o}C.

The accumulated gas pressure of each bottle was recorded at 5 min intervals for the 30 h incubation period. The release pressure was set at 1 psi. Gas pressure values were converted to gas volume (ANKOM Technology, 2012). Each module was slowly shaken at 2 h intervals to ensure feed bags were fully immersed in the rumen fluid/buffer. At completion of 30 h incubation, ruminal fluid pH was recorded and samples taken for VFA and NH_3-N measurements. The nylon bags containing digested feed were repeatedly washed in cold running water until completely clean and then dried at 55^{o}C for 48 h and residue weight recorded for calculation of dry matter digestibility. The digestibility of NDF was then measured as the difference between the amount of NDF in the TMR before and after the in vitro fermentation. Original TMR samples and residues from in vitro digestion were then subjected to NDF assay, which was used to calculate fiber (NDF) digestibility. Cumulative gas production for the 30 h was fitted to the following equation: gas = b × (1- e^ (- c × h)) using nonlinear regression to determine the kinetic rates of gas production.

Statistical analysis

All data were analyzed subjected to least squares analysis of variance using the PROC MIXED procedure of SAS (9.4) with the treatments arranged in a randomized complete block design (RCBD). Sources of variation were block, replication, and treatment. Block and replication were considered to be random effects and treatment was considered a fixed effect in the model. Significance was declared at $P < 0.05$.

Model used for this experiment was as follows:

$$Y_{ij} = \mu + T_i + B_j + e_{ij}$$

Where,

Y_{ij} is the dependent variable

μ is the overall mean

T_i is the i^{th} treatment effect (i = 1,2,3,4)

B_j is the j^{th} block effect (1,2,3,4)

e_{ij} is the error term

RESULTS AND DISCUSSION

Chemical composition of water

Chemical composition of experimental water samples collected from different sources, average farm water composition from South Dakota State (Casper, 2012) and normal range of water composition (Bagley et al., 1997) are presented in Table 2.3. Total dissolved solid (TDS), sulfate, and hardness concentrations were found to be higher than normal for FU, FT and MW, but within the normal concentrations for DW. Similarly, levels of Ca, Mg, Fe, and total bacterial counts were higher than normal in water from FU and FT, but within normal concentrations for DW water. This indicates that South Dakota water is higher in TDS, sulfate, hardness and bacterial counts and need to treat before being offered to dairy cows. Patterson et al. (2003) also reported high TDS and sulfates in water available to beef cattle in South Dakota. Data from SDSU laboratory showed water samples collected from wells and stock dams in western South Dakota to have TDS as high as 15,000 ppm and sulfates as high as 10,000 ppm (Patterson et al., 2003). The impacts of poor quality water on beef and dairy production have not been clearly documented. However, higher concentration of dietary sulfur caused by intake of high sulfate water can cause polioencephalomalacia (PEM) in cattle (McAllister et al., 1997). Sulfur induced PEM leads to neurological disorder, gastrointestinal stasis, anorexia, blindness, and potentially death. Increase TDS and sulfates in the water reduced performance and health of growing steers (Patterson et al., 2003). Data from the USDA's National Animal Health Monitoring System (APHIS, 2000) showed water samples collected in South Dakota feedlots averaged 2000 ppm TDS and over 1000 ppm sulfates.

Challis et al. (1987) compared the productivity of dairy cows offered well water containing 4000 to 5000 ppm of total dissolved solids with desalinated water and reported higher water intake, DMI and milk production in group of cows received desalinated water compared to raw well water. Grout et al. (2006) reported decline in water consumption with rising SO_4 levels in water.

Ruminal pH, ammonia and volatile fatty acids

Data obtained from analysis of rumen samples for pH, ammonia and volatile fatty acids (VFAs) are presented in Table 2.4. Rumen pH while using different sources of water were similar ($P < 0.05$) between treatments. The accepted pH range of drinking water for most of the livestock is 6 to 8 (Hersom and Crawford, 2008; Bagley et al., 1997). The pH affected water quality by altering taste, efficacy of chlorination, corrosive potential and several other properties (Hersom and Crawford, 2008). The water pH value lower than 5.5 may result in acidosis, associated with weight loss and production in cattle. The pH of water outside of accepted range may cause diminished water and feed intake, digestive upsets, diarrhea, poor feed conversion (Looper, 2012). Grant (1996) reported that water with a pH of less than 5.5 may cause problems related to mild acidosis such as reduced milk yield, depressed milk fat percentage, low daily gains, more infectious and metabolic disease, and reduced fertility. Alkaline water of pH greater than 8.5 may result in problems related to mild alkalosis, such as amino acid and B-vitamin deficiencies, and symptoms similar to mild acidosis (Grant, 1996). Rumen ammonia concentration (mg/dL) was lower ($P < 0.05$) for DW compared to FU, FT and MW. Hence, the use of laboratory distilled water (DW) to measure in vitro digestion underestimates ammonia production and possibly overestimates the microbial protein synthesis. Similarly, a trend of lower ($P < 0.10$) VFAs concentrations (mmol/L) for the DW was observed when compared to MW water source implying that the use of distilled water underestimates total VFAs production. Using DW to measure feed digestion underestimates total acetate production compare to MW. The production of butyrate and isobutyrate were overestimated while using DW compare to MW and FT water, respectively. Valerate concentration was overestimated by DW compared to MW. Thus, use of laboratory distilled water to run in vitro gas production measurement has huge impact on ruminal fermentation patterns compared to real farm water offer to the cows.

Nutrient digestibility

Total DMD and total NDFD of TMR are presented in Table 2.5. Total DMD tended to be lower ($P < 0.10$) in MW water compared to others. However, total NDFD was similar ($P > 0.05$) across all water samples used in the experiment. Past research on water safety and palatability has raised awareness of the importance of good quality water for dairy cows. However, studies done so far are lacking on how water quality may affect ruminal fermentation and digestion. Some studies have pointed out accepted water quality level as safe for cows to drink, but still silent about actual optimal level. A change in digestibility rate because of change in water quality can have noteworthy impacts on milk yield. A 2% unit drop in digestibility can reduce dry matter intake by 0.34 kg/d, and milk output by 0.46 kg/d (Andreen, 2015).

Gas production and measurements

Actual and blank corrected regression coefficients of in vitro gas production with different sources of water are presented in Table 2.6. Regression coefficients were greater ($P < 0.05$) for DW compared to FU, FT and MW water sources. Use of distilled water (DW) to determine in vitro gas production of any TMR or feed sample inflates the rate of digestibility compared to what would be expected on the dairy operation. Total in vitro gas production (psi) from different sources of water is presented in Figure 2.2. Total gas production was higher ($P < 0.05$) for DW water compared to FU, FT and MW water. Use of laboratory distilled water (DW) overestimated the in vitro gas production when compared to the use of actual dairy operation water that is offered to the cows. The reason for the high gas production might be due to low or no availability of minerals and microbes in distilled water depressing the growth of methane producing microorganism in the rumen.

CONCLUSIONS

South Dakota water is higher than normal range in TDS, sulfate, hardness, Ca, Mg, Fe, and bacterial counts and need to treat before offer to dairy cows. The source and nutrient quality of water can affect rate of ruminal fermentation. The use of laboratory distilled water may bias upwards digestibility coefficients compared to what is actually observed on the dairy operation. Thus, the use of laboratory distilled water may result in digestibility coefficients that are not applicable to dairy operations. The use of a water treatment system had minimal influence on the measurements of ruminal fermentation and digestibility in this study. However, the use of a water treatment system may still benefit the animal separately from effects on ruminal fermentation while considering total bacterial count. In conclusion, use of laboratory distilled water to determine rates of digestibility coefficients using an in vitro gas production system may not accurately predict the ruminal fermentation, digestibility and total gas production of that same feed on the dairy operation. Thus, use of real farm water being offered to the cow to conduct in vitro gas production measurements may accurately predict the ruminal fermentation, digestibility and total gas production. However, more research should be conducted to confirm these findings.

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Table 2.1. Chemical composition of Mould’s buffer (Reference procedure 080221)

List of chemicals	Units	Quantity used
Distilled Water (dH_2O)	mL	2070.000
Sodium Phosphate Diabasic (Na_2HPO_4)	g	1.830
Potassium Phosphate (KH_2PO_4)	g	3.020
Magnesium Chloride Hexahydrate ($MgCl_2$)	g	0.244
Ammonium Bicarbonate (NH_4HCO_3)	g	3.260
Sodium Bicarbonate ($NaHCO_3$)	g	12.570
Resazurin (1g/L solution)	mL	2.300

Table 2.2. Chemical composition of reducing solution

List of chemicals	Units	Quantity used
Distilled Water (dH_2O)	mL	250
Cysteine HCL ($C_3H_7NO_2S.CIH$)	g	0.905
Sodium Hydroxide (NaOH)	g	0.232

Table 2.3. Chemical composition (ppm unless noted) of water from different sources used on an in vitro gas production measurement system

	Sources of water[1]					Normal
Laboratory analysis	DW	FU	FT	MW	SD State[2]	Ranges[3]
Nitrate N	0.00	0.00	1.00	0.00	1.00	0 to 9
pH, scale	6.20	7.10	7.00	8.40	7.40	6.5 to 7.5
TDS	2.00	4500.00	4300.00	454.00	1241.00	<1000
Sulfates	0.00	579.00	595.00	227.00	166.70	<150
Ca	1.00	232.00	233.00	49.00	166.80	40 to 120
Mg	0.00	94.00	94.00	37.00	66.30	16 to 50
K	0.00	7.00	7.00	3.00	8.90	0 to 10
Na	0.00	70.00	71.00	21.00	89.90	20 to 100
Cu	0.00	0.00	0.00	0.01	0.02	<1
Mn	0.00	0.33	0.28	0.03	0.42	<0.05
Zn	0.01	0.04	0.02	0.00	0.24	<20
Fe	0.00	13.93	5.87	0.82	1.61	<1
Cl	157.00	4.00	4.00	20.00	27.50	<25
Hardness	2.00	966.00	968.00	274.00	-	0 to 60
Bacteria, CFU/100 mL	0.00	40.00	40.00	0.00	27.60	0

[1] DW = distilled water, FU = untreated local farm water, FT = H_2O_2 treated local farm water, MW = municipal rural water supply

[2] Adapted from Casper et al. (2012)

[3] Adapted from Bagley et al. (1997)

Table 2.4. Rumen pH, ammonia and VFAs composition when a single TMR is evaluated with different sources of water using an in vitro gas production measurement system

	Sources of water[1]				
Analysis	DW	FU	FT	MW	SEM
Rumen pH	6.47	6.53	6.41	6.52	0.07
Ammonia, mg/dL	23.4^{b}	27.7^{a}	25.9^{ab}	28.7^{a}	1.65
Total VFA, mmol/L	67.31^{d}	80.65^{cd}	94.92^{cd}	107.38^{c}	10.20
--------------------------------(mmol/100 mmol of total VFA---------------------------------					
Acetate	65.46^{b}	65.67^{ab}	65.99^{ab}	66.98^{a}	0.33
Propionate	24.02	24.46	24.34	23.53	0.37
Iso-butyrate	0.84^{c}	0.77^{cd}	0.76^{d}	0.77^{cd}	0.02
Butyrate	7.33^{c}	7.01^{cd}	6.88^{cd}	6.77^{d}	0.15
Iso-valerate	1.09^{c}	0.93^{d}	0.92^{d}	0.93^{cd}	0.05
Valerate	1.25^{a}	1.16^{ab}	1.11^{b}	1.07^{b}	0.04
Ace:Prop ratio	2.75	2.70	2.72	2.88	0.05

^{a,b,}Least squares means within the same row without a common superscript differ ($P < 0.05$)

^{c,d}Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] DW = distilled water, FU = untreated local farm water, FT = H_2O_2 treated local farm water, MW = municipal rural water supply

Table 2.5. Dry matter digestibility and neutral detergent fiber digestibility when a single TMR is evaluated with different sources of water using an in vitro gas production measurement system

	Sources of water[1]				
Analysis	DW	FU	FT	MW	SEM
DMD	81.99^{c}	81.61^{cd}	80.82^{d}	81.61^{c}	0.44
NDFD	60.37	59.43	58.69	59.98	0.94

^{c,d}Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] DW = distilled water, FU = untreated local farm water, FT = H_2O_2 treated local farm water, MW = municipal rural water supply

Table 2.6. Regression coefficients of gas production when a single TMR is evaluated with different sources of water using in vitro gas production measurement system

	Sources of water[1]				
Analysis	DW	FU	FT	MW	SEM
Raw					
b	10.68	10.97	10.62	10.85	0.20
c	12.64	12.41	12.70	12.37	0.37
Corrected					
b	5.87^{c}	5.00^{d}	5.43^{cd}	5.05^{d}	0.51
c	16.37^{a}	9.50^{b}	9.66^{b}	9.71^{b}	0.98

^{a,b,}Least squares means within the same row without a common superscript differ ($P < 0.05$)

^{c,d}Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] DW = distilled water, FU = untreated local farm water, FT = H_2O_2 treated local farm water, MW = municipal rural water supply

Figure 2.1. Components of Ankom in vitro Gas production measurement system (ANKOM Technology, 2012)

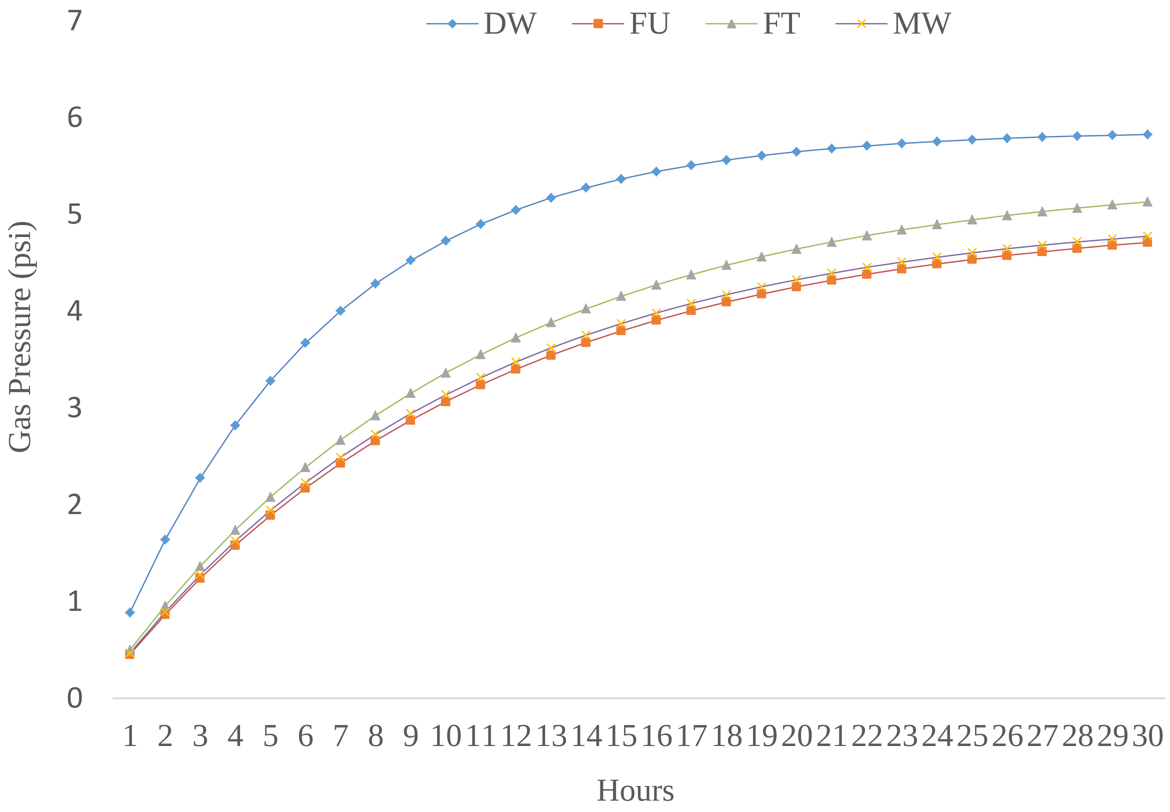

Figure 2.2. Total gas production when a single TMR is evaluated with different sources of water using an in vitro gas production measurement system (DW = distilled water, FU = untreated local farm water, FT = H_2O_2 treated local farm water, MW = municipal rural water supply)

CHAPTER 3

LACTATIONAL PERFORMANCE OF EARLY LACATATION HIGH PRODUCING DAIRY COWS FED CORN SILAGE PRODUCED BY DIFFERENT SEED CORN HYBRIDS

ABSTRACT

The objective of this study was to evaluate the nutrient intake and milk production response of early lactating dairy cows fed diets based on corn silage produced from 3 different corn silage hybrids. Twenty-one (6 primiparous and 15 multiparous) high producing early lactation Holstein cows were fed one of three experimental corn silages harvested from the planting of three different seed corn hybrids from wk 4 through wk 12 postpartum. Corn hybrids Dekalb blend (Starchy), Masters Choice 527 (LF_1) and Masters Choice 5250 (LF_2) were planted and harvested as corn silage using a kernel processor silage harvester, inoculated, and ensiled in individual Ag Bags. Total mixed rations were formulated to be isonitrogenous at 17.5% CP consisting of 15.9% alfalfa hay, 35.1% concentrate mix and 48% of the respective experimental corn silage on DM basis. Cows were blocked by calving date and parity and randomly assigned to 1 of 3 treatments in a randomized complete block design. Data collected the third wk postpartum was used as a covariate in Least Squares Analysis of Covariance via the PROC MIXED procedure (SAS Institute). Crude protein content of LF_1 corn silage was higher than LF_2 and Starchy silage. Starch content was higher for Starchy corn silage compared to LF_1 and LF_2 silage. The calculation of Digestible NDF per unit of dry matter in the TMR was lower for the Starchy than LF_1 and LF_2 (14.0%, 15.5, and 17.9% DM).

LF$_1$ and LF$_2$ hybrids supplied more digestible fiber than the Starchy hybrid. Growing year affected vomitoxin concentrations on silage and may affect dairy cow performance as Starchy hybrid was grown in 2013 crop year and LF$_1$ and LF$_2$ were grown in 2012 crop year. Dry matter intake (22.9, 23.5, and 22.4 kg/d for Starchy, LF$_1$, and LF$_2$, respectively), milk yield (35.6, 34.8, and 36.1 kg/d), 3.5% fat-corrected milk (FCM) yield (38.7, 36.5, and 37.6 kg/d), energy corrected milk yield (38.2, 36.1, and 38.1 kg/d), feed efficiency (1.79, 1.61, and 1.67 kg/kg; 3.5% FCM/ DMI), milk fat (4.17, 3.94, and 3.71%), milk protein (3.12, 3.09, and 3.03%), lactose (4.93, 4.92, and 4.92%), solid-not-fat (8.96, 8.92, and 8.85%), body weight change (-0.10, -0.06, and -0.08 kg/d), and body condition score change (-0.05, -0.04, and -0.05 score/d) were similar ($P > 0.05$) for early lactation dairy cows fed all corn silage hybrids. Milk urea nitrogen was lower ($P < 0.05$) for cows fed Starchy corn silage diet compared to cows fed LF$_1$ and LF$_2$ corn silage diets (13.6, 15.0, and 15.0 mg/dL for Starchy, LF1 and LF2 experimental diets respectively). Lower ruminal pH and acetate molar percentage and higher propionate molar percentage were reported with Starchy corn hybrid silage compared to LF$_1$ and LF$_2$ but similar ruminal NH_3-N content across the experimental diets. This study demonstrated that a lower starch content with higher starch digestibility, and higher digestible fiber (DNDF) corn silage diets can support similar milk production compared to a higher starch content with lower starch digestibility, and lower digestible fiber corn silage diets.

Key words: corn silage, corn hybrids, high producing dairy cows

INTRODUCTION

Costs of grain and various feed ingredients have increased dramatically in recent years. In addition, the availability of certain commodities has become scarce in certain parts of the country. The result is that rations fed to livestock and in particular, lactating dairy cows, have risen dramatically in cost. In the past, commodities and by-products have been used to reduce ration costs and improve profitability of the dairy operation. However, even these commodities are increasing in cost due to value and availability relative to corn and soybean meal. Therefore, new ways must be found to reduce feed costs to regain profitability and sustainability of the dairy industry to compete on a world market.

Whole-plant corn harvested as silage is a key ration component in many diets fed to dairy cattle, and its use continues to increase in lactating dairy cattle diets. Corn silage is normally a high-energy forage with high yield potential on per hectare basis compared to other forage crops. Various types of corn hybrids are available for use as silage in dairy cattle diets including waxy, high lysine, brown midrib, high oil, and leafy hybrids. Continuous selection of corn hybrids for silage has increasingly highlighted improved NDF digestibility in addition to high grain content and overall DM yield (Nennich et al., 2003). If we go through published literature, we can found several studies that compared different corn silage hybrids on dairy cattle performance (Barriere et al., 1995; Oba and Allen, 1999a; Kuehn et al., 1999; Bal et al., 2000b; Ballard et al., 2001; Thomas et al., 2001; Clark et al., 2002). The BMR trait is the only one that consistently showed an improvement in milk production (Oba and Allen, 1999a; Bal et al., 2000b; Ballard et al.,

2001) among the available corn silage hybrid types. Most studies have shown little or no changes in milk yield when leafy corn silage hybrids were fed to lactating dairy cows (Kuehn et al., 1999; Bal et al., 2000b; Ballard et al., 2001). However, research conducted by Thomas et al. (2001) and Clark et al. (2002) reported higher milk yield while feeding leafy corn silage hybrids relative to conventional corn silage hybrids. Use of leafy corn silage hybrids in dairy cow rations often has not improved feed intake over rations containing conventional corn hybrids (Kuehn et al., 1999; Bal et al., 2000b; Thomas et al., 2001). But, Ballard et al. (2001) and Clark et al. (2002) reported higher feed intake by lactating dairy cows when offer a leafy corn silage hybrid compared to a conventional corn silage hybrid.

Although past research has not shown a steady increase in milk production or DMI from feeding a particular corn silage hybrid, improved corn silage hybrids are introduced to the marketplace every year. With release of new corn hybrids, it is essential to evaluate their agronomic traits, as well as, their response on dairy cattle performance. Masters Choice (Anna, IL) developed MC 527 (LF_1) and MC 5250 (LF_2) new corn silage hybrids, which they described, were selected for increased silage yield, milk yield, sugars, fiber, and starch digestibility. We hypothesized that feeding of new corn silage hybrids (LF_1 and LF_2) will result in greater milk production compared to the conventional Dekalb blend corn grain hybrid (Starchy).

OBJECTIVES

The objective of this study was to evaluate new leafy floury corn hybrids MC 527 (LF_1) and MC 5250 (LF_2) silage against conventional Dekalb blend corn grain hybrid

(Starchy) silage for nutrient composition, DMI, digestibility and lactation performance of early lactating dairy cows.

MATERIALS AND METHODS

Corn planting, harvest and silage production

Three different corn silage hybrids, namely Dekalb blend (Starchy; silage produced from blend of DKC48-12 RIB Brand Blend, DKC 52-29 RIB Brand Blend and DKC 53-78 RIB Brand Blend, Monsanto Company, St. Louis, MO), MC 527 ($LF_{1;}$ 105 d maturity, Masters Choice Seed Corn, Anna, IL) and MC 5250 (LF_2; 102 d maturity, Masters Choice Seed Corn, Anna, IL) were planted at the Dairy Research and Training Facility, South Dakota State University according to their recommended seeding rates of 86,487/ha and common agronomic practices. Fields were fertilized according to soil report recommendations and cultivated before planting. The LF_1 and LF_2 corn silage hybrids were grown and harvested during the 2012 crop year and Starchy corn silage hybrid was grown and harvested the 2013 crop year. Corn silage was harvested at recommended days of respective varieties with a John Deere 6750 self-propelled forage harvester (John Deere, Moline, IL). After harvesting, corn silage was treated with *lactobacillus* inoculant (Silo-King® Plus, Agriking Inc., Fulton, IL) and ensiled in an Ag-Bag (Ag-Bag, St. Nazianz, WI) and allowed to ferment until fed to the trial cows.

Animals, diets and experimental design

This study was conducted at the Dairy Research and Training Facility (DRTF) of South Dakota State University, Brookings on year 2013/2014. All cows were cared and managed according to SDSU Institutional Animal Care and Usage Committee recommendations. Cows were housed in a free-stall barn and fed covariate diet (control Starchy diet) as a TMR immediately after calving using the Calan Broadbent feeder door and box system (American Calan, Inc., Northwood, NH). Cows remained on the covariate diet for 3 wk postpartum, after which they were assigned to 1 of 3 dietary treatments if they were healthy and normal. Cows were blocked by calving date and parity using a randomized complete block design. Twenty-one (6 primiparous and 15 multiparous) high producing early lactation Holstein cows were fed one of three experimental corn silages harvested from the planting of three different seed corn hybrids from wk 4 through wk 12 postpartum.

Cows were fed individually their assigned diets once a day at 0600 h to allow 5-10% refusals. The diets were fed as a TMR and contained similar ingredients in equal proportion, except types of corn silage. All diets contained 63.9% forage (24.9% alfalfa hay and 75.1% corn silage), and 36.1% concentrate (Table 3.2) on a DM basis. Diets were formulated to be approximately 17.5% CP, 24.5% Starch, 33.9% NDF, 20.1% ADF, 5.6% ether extract (EE), and were equal in estimated NE_L at 1.61 Mcal/kg DM with all other nutrients formulated to meet or exceed the requirements according to the NRC (2001) for a cow weighing 682 kg, producing 41 kg milk with 3.7% fat and 3.1% protein. Agricultural modelling and training systems (AMTS) software (AMTS LLC, Groton, NY) was used to formulate the balanced ration. Diets formulation and proportions of ingredients were exactly similar except types of experimental silage. Rumensin and rBST were not used in entire trial period. The control TMR (Starchy) was used as the covariate diet. Cows were milked three times daily at 0700, 1500 and 2200 h with milk production recorded electronically (Delaval-Alpro, Kansas City, MO).

Body weight and body condition scores (BCS) were taken at the end of every week including the covariate period. The BCS were recorded independently by three experienced individuals at the start of the study (covariate) and at the end of each week. The BCS were taken by using a scale of 1 to 5, with 5 being obese and 1 being emaciated as described by Wildman et al. (1982) and Edmonson et al. (1989).

Sample collections

Individual ingredients, concentrate mix, TMR and orts samples were taken weekly, composited by month and subsamples were used for analysis of nutrient content. Silage and hay samples were checked for DM on a weekly basis, and diets were adjusted to maintain ingredients at constant percentage of the diet DM. Samples of TMR were taken weekly to measure particle size using the Penn State Particle Separator (Kononoff et al., 2003). The amounts of particles retained on the different screens were weighed and recorded.

Milk samples were collected at all three milking times once weekly. Milk samples were composited on a percentage by milk yield basis and sent to Heart of America DHI laboratory (Manhattan, KS) for compositional and quality analysis using AOAC (2002) approved methods. The remaining of composited samples were used to analyze milk protein fraction and milk fatty acid composition.

Rumen fluid samples were collected via an esophageal tube fitted with a suction strainer and hand operated pump on one day at wk 3, 6, and 9 of the experimental period approximately 3 h after feeding. The first 100 mL of rumen fluid was discarded to minimize saliva contamination. After collection, rumen fluid was mixed thoroughly and pH was measured immediately using an electronic pH meter (Corning 350, Corning Inc., Corning, NY). If the rumen fluid collected was at a pH >7.0, rumen fluid was discarded and additional rumen fluid was collected to ensure minimal saliva contamination. Two 10-mL samples of rumen fluid were collected, where one 10-mL sample was added to a vial containing 200 μL of 50% (vol/vol) H_2SO_4 for later determination of NH_3-N and the other 10-mL sample was added to a vial containing 2 mL of 25% (wt/vol) meta-phosphoric acid for later determination of VFAs. After sample collection and preparation, rumen fluid samples were immediately stored at −20°C for further analysis.

Sample analyses

Feed samples (TMR, concentrate mix and individual ingredients) were composited by month and dried at 55^{o}C for 48 h in a dispatch oven (Style V-23; Dispatch oven Co., Minneapolis, MN). Composites of feed samples were ground to a 4 mm particle size (Wiley mill, Arthur H. Thomas Co., Philadelphia, PA), and then further ground to a 1 mm particle size using an ultracentrifuge mill (Brinkman Instruments Co., Westbury, NY). The DM was determined by taking approximately 1 g of ground sample and drying at 105^{o}C for 4 h, for correction to 100% DM. Ash was determined by heating samples in a muffle furnace at 450^{o}C for 8 h (Understander et al., 1993). Samples were analyzed for NDF, ADF and ADL sequentially via Ankom filter bag analysis system

(Ankom Technology Corp., Fairport, NY). The method for NDF was based upon procedures described by Van Soest et al. (1991) using heat-stable α-amylase and sodium sulfite. The method for ADF was based upon procedures described by Robertson and Van Soest (1981). The method for ADL was based upon procedures explained by Lowry et al. (1994). Ether extract was determined using Ankom filter bag analysis procedure AM-5-04 (2001) with petroleum ether as the solvent. Crude protein was determined using Elementar rapid N-cube nitrogen determination (Elementar Americas Inc., Mt. Laurel, NJ), based on AOAC method 993.13 (AOAC, 1996).

The fat, protein and lactose of milk sample were analyzed by near infrared spectroscopy (Bentley 2000 Infrared milk Analyzer, Bentley Instruments, Chaska, MN). The MUN concentration was determined using a chemical method based on a modified Berthelot reaction (Chaney and Marbach, 1962; ChemSpec 150 Analyzer, Bentley Instruments). Somatic cell counts were determined with a flow cytometer laser (Somacount 500, Bentley Instruments). Energy-corrected milk (ECM) was calculated using the equation: [(0.327 × kg milk) + (12.95 × kg fat) + (7.20 × kg protein)] and 3.5% FCM was calculated using the equation: (0.4324 x kg of milk) + (16.216 x kg of milk fat) as described by Orth (1992).

Rumen fluid samples preserved in 50% H_2SO_4 were used to determine rumen NH_3-N concentrations as described by Chaney and Marbach (1962) and Weatherburn (1967). Rumen fluid samples preserved in 25% metaphosporic acid were used to determine VFAs concentrations using a gas chromatography (Model 6890, Hewlett-Packard, Palo Alto, CA) having a flame ionization detector. The injector port was at a temperature of 250°C with a split ratio of 30:1. The column was 15 m in length and 0.25 mm in diameter (Supelco Inc., Bellefonte, PA). Flow rate was 1.3 mL/min of Helium. Column and detector temperature were maintained at 130 °C and 225°C, respectively.

Statistical analysis

Milk production and composition, and feed intake data from the lactation study were analyzed as a randomized complete block design with three corn silage dietary treatments and 7 replicates. Cows were blocked according to calving date. Individual cow data from the covariate period of the study was included in the model. The least significant difference method was utilized to compare treatment means when the ANOVA F test was significant. All results are reported as least squares means. Differences among treatments were considered significant at $P < 0.05$. The PROC MIXED procedure of SAS 9.4 was used for all statistical analyses.

Model used for this experiment was as follows:

$$Y_{ij} = \mu + T_i + B_j + COV_k + e_{ij}$$

Where,

Y_{ij} is the dependent variable

μ is the overall mean

T_i is the i^{th} treatment effect ($i = 1, 2, 3$)

B_j is the j^{th} block effect ($j = 1, 2,\ldots\ldots 7$)

COV_k is the k^{th} pretreatment parameter used as covariate

e_{ijk} is the error term

RESULTS AND DISCUSSION

Temperature and rainfall patterns of crop growing season

The growing season of 2012 was drier and hotter than normal, but 2013 growing season was closer to normal (Table 3.1), while considering average temperature and precipitation for past 30 years. Thus, corn silage produced in the 2012 year (LF_1 and LF_2) was stressed by the drought and high temperatures compared to silage produced in the 2013 year (Starchy). Crop production data were not recorded since the fields were not replicated.

Nutrient composition of experimental diets

The ingredients and their proportion used to formulate the different experimental diets are presented in Table 3.2. Control (Starchy) diet was used as covariate diet. All experimental diets were similar in ingredient proportions and only differed in type of silages used. Chemical composition of individual ingredients and final experimental diets are presented in Table 3.3. Corn silage produced from LF_1 corn seed hybrids was higher in CP value compared to Starchy and LF_2 hybrids. Concentration of vomitoxin (ppm) was higher ($P < 0.05$) for LF_1 and LF_2 compared to Starchy silage, which might be associated with difference in crop growing season. Crop growing year for LF_1 and LF_2 silage of 2012 was hotter and dried than Starchy silage growing year of 2013. Although, we tried to balance CP level around 17.5%, final experimental diets were a little higher than expected. Starchy diets were about 0.5% lower in CP compared to LF_1 and LF_2 which was due to higher CP content of LF1 and LF2 corn silage and diet was formulated based on nutrients content of Starchy silage. Total NDF content was higher ($P < 0.05$) in LF_2 followed by LF_1 and Starchy. Lignin content of LF_1 and LF_2 diets were higher ($P < 0.05$) compared to Starchy diets which follows the trend of lignin as in silages. Starch content was higher ($P < 0.05$) in Starchy diets followed by LF_1 and LF_2 as expected. Sugar content of LF_1 and LF_2 diets were higher ($P < 0.05$) compared to Starchy diets as expected. The NDFD for 30 h was higher ($P < 0.05$) for LF_2 diets compared to Starchy diets with LF_1 being intermediate. Although, there were some differences between the diets in macro minerals concentration, we didn't expect any variation in performance since all values were close or little higher than nutrients requirements as suggested by NRC (2001).

Chemical composition of experimental silages analyzed at Rock River Laboratory, Inc. (Watertown, WI) reported higher ($P < 0.05$) CP and available CP in LF_1 silage, LF_2 being intermediate and Starchy silage being the lowest (Table 3.4). However, higher ($P < 0.05$) amount of SP was reported for Starchy silage compared to LF_1 and LF_2 silage. Neutral detergent insoluble crude protein (NDICP) was higher ($P < 0.05$) for LF_1 and LF_2 silage compared to Starchy but ADICP (Acid detergent insoluble crude protein) was similar ($P > 0.05$) among experimental silages. NDF content was higher ($P < 0.05$) for LF_2 than LF_1 but Starchy was intermediate. Undigestible neutral detergent fiber for 30 h (uNDF30) was similar ($P > 0.05$) among the experimental silages. However, undigestible neutral detergent fiber for 120 and 240 h (uNDF120 and uNDF240) were higher ($P < 0.05$) for LF_2 silage compared to Starchy and LF_1 silage. Total tract neutral detergent digestibility (TTNDF) and dynamic NDF digestion rate (kd) were similar ($P > 0.05$) among the experimental silages. Total starch content was higher ($P < 0.05$) for Starchy silage compared to LF_1 and LF_2 silage as expected. Soluble starch value and 7 h starch digestibility (isSD7) were higher ($P < 0.05$) for LF_1 silage compared to Starchy with LF_2 being intermediate. Nennich et al. (2003) compared conventional corn silage hybrids with two leafy corn silage hybrids and reported similar starch digestibility while feeding to lactating dairy cows. Ferraretto et al. (2014b) also reported greater in vivo starch digestibility for leafy floury corn silage compared to BMR silage. On contrast, Morrison et al. (2014) reported similar starch digestibility for leafy starchy and BMR silage diets. Total sugar content value was double in LF_1 and LF_2 silage compared to Starchy, as expected. However, experimental silages were similar in terms of fat, lignin and ash content. Lactic acid concentration was higher ($P < 0.05$) in Starchy silage, while ammonia concentration was reported higher ($P < 0.05$) in LF_1 and LF_2.

Particle size distributions of experimental TMRs

Particle size distributions of experimental TMRs are presented in Table 3.5. The percentage of TMR particles on the upper sieve of the Penn State Particle Separator (PSPS) was higher ($P < 0.05$) for LF_1 and LF_2 TMR compared to the Starchy TMR. However, particle amounts on the upper sieve were within the recommended range for PSPS. The percentage of TMR particles on the middle sieve of the PSPS was higher ($P < 0.05$) in LF_1 than LF_2 and Starchy being intermediate. Still, particles amount on the middle sieve were within the recommended range for PSPS. The percentage of TMR particles on the lower sieve was tended to be higher ($P < 0.10$) in LF_2 than LF_1 but within the recommended range for PSPS. The percentage of TMR particles on bottom pan was lower ($P < 0.05$) in LF_1 compare to Starchy and LF_2. However, particles amount on the bottom pan were within the recommended range for PSPS. Since, all values from PSPS screens were within the recommended ranges, we were not expecting any effects on animal performance because of variation in TMR particle size.

Dry matter intake

Dry matter intake of cows fed different experimental diets is presented in Table 3.6 and Figure 3.1. Dry matter intake (kg/d) was not different ($P > 0.05$) across three corn silage experimental diets ranging from 22.43 to 23.50. Correspondingly, Kuehn et al. (1999), Thomas et al. (2001) and Nennich et al. (2003) reported similar DMI between the diets containing conventional and leafy corn silage hybrids. In contrast, Clark et al. (2002) reported 0.9 kg/d higher DMI for diets containing a leafy corn silage hybrid as opposed to a conventional corn silage hybrid.

Milk yield and composition

Milk yields (Figure 3.1) and milk compositions are presented in Table 3.6. Milk yield (kg/d) was similar ($P > 0.05$) across three corn silage experimental diets ranging from 34.84 to 36.10. Kuehn et al. (1999), Ballard et al. (2001) and Nennich et al. (2003) also reported similar milk yields when conventional and leafy corn silage hybrids were fed to lactating dairy cows. However, Thomas et al. (2001) and Clark et al. (2002) reported higher milk yield by cows fed diets containing leafy corn silage hybrids than cows fed conventional hybrids. Milk fat percentage and milk protein percentage were similar ($P > 0.05$) across the three silage experimental diets. Milk fat and milk protein yield (kg/d) were not different ($P > 0.05$) among treatments, ranging from 1.34 to 1.47 for milk fat and 1.07 to 1.12 for true milk protein. Nennich et al. (2003) reported similar milk fat percentage, milk protein percentage, milk fat yield, and milk protein yield when conventional and leafy corn silage hybrids were fed to lactating dairy cows. Clark et al. (2002) reported a 0.05 kg/d increase in milk fat production for cows fed a leafy corn silage hybrid diet compared with a diet containing conventional corn silage hybrids. In contrast, Thomas et al. (2001) reported a trend toward greater protein yield from cows fed a leafy corn silage hybrid diet. Lactose percentage, SNF percentage, and SCC were similar ($P > 0.05$) across the treatments. Similar milk SCC was reported by Nennich et al. (2003) when conventional and leafy corn silage hybrids were fed to lactating dairy cows. Yield of 3.5% FCM were not different ($P > 0.05$) at 38.68, 36.46, 37.59 kg/d for Starchy, LF_1 and LF_2 diets, respectively. Kuehn et al., (1999), Bal et al. (2000b), Ballard et al. (2001), and Nennich et al. (2003) also reported no improvement in FCM yield from feeding leafy corn silage hybrids over conventional corn silage hybrids, whereas Thomas et al., (2001), and Clark et al., (2002) reported an increase in FCM yield while feeding leafy corn silage hybrids over conventional corn silage hybrids. Yield of ECM were not different ($P > 0.05$) at 38.21, 36.13, 38.10 kg/d for Starchy, LF_1 and LF_2 diets, respectively. MUN, mg/dL was lower ($P < 0.05$) for diet having Starchy silage (13.64) compared to diet having LF_1 and LF_2 silages (14.99) which followed the CP content of the experimental diets. Since, Starchy diets has about 0.5% lower CP compared to LF_1 and LF_2 diets, we were expecting lower MUN in Starchy than LF_1 and LF_2 diets.

Body weight and body condition score

Body weight (BW) and body condition score (BCS) data are presented in Table 3.6. Cows fed Starchy, LF_1 and LF_2 diets had similar ($P > 0.05$) BW (646.66, 647.69, and 647.83 kg BW for Starchy, LF_1, and LF_2 diets respectively) throughout the lactation study. The average daily change in BW over the 9 wk lactation study for cows fed Starchy, LF_1 and LF_2 diets were similar ($P > 0.05$; - 0.10, - 0.06, and - 0.08 kg/d respectively). The average daily change in BCS over the 9 wk lactation study for cows fed Starchy, LF_1 and LF_2 diets were similar ($P > 0.05$; - 0.05, - 0.04, and - 0.05 respectively). Cows on all treatments were losing body weight and BCS as expected in early lactation period.

Ruminal pH, ammonia, and volatile fatty acids

The pH, ammonia and volatile fatty acids composition of rumen fluid of cows fed experimental diets differing in hybrid corn silage are presented in Table 3.7. The value of rumen pH was lower ($P < 0.05$) for Starchy compared to LF_1 and LF_2 experimental diets. The high starch content of Starchy diets ended with higher fermentation and lower pH compared to low starch diets of LF_1 and LF_2. Low ruminal pH was also reported by Cherney et al. (2004) when cows fed BMR and conventional corn hybrid silage compared to leafy corn hybrid silage. Rumen NH_3 concentration (mg/dL) was similar ($P > 0.05$) across the experimental diets. Total VFA concentration (mmol) was higher ($P < 0.05$) for Starchy diet compared to LF_1 diet but intermediate for LF_2 diets. Molar proportion of acetate was higher ($P < 0.05$) for LF_1 and LF_2 diets compared to Starchy diet as expected. Higher NDF content and NDF digestibility of LF_1 and LF_2 diets produced more acetate compared to Starchy as shown in Table 3.3. Molar proportion of propionate was higher ($P < 0.05$) for Starchy diets compared to LF_1 and LF_2 diets. High starch content of Starchy diets produced more propionate than low starch content diets of LF_1 and LF_2. Molar proportion of isobutyrate, butyrate and valerate were similar ($P > 0.05$) among the experimental diets. However, molar proportion of isovalerate was reported higher ($P < 0.05$) for Starchy diet compared to LF_2 diet and LF_1 being intermediate. Ratio of acetate to propionate and acetate, butyrate to propionate was higher ($P < 0.05$) for LF_1 and LF_2 diets compared to Starchy diets as expected. Holt et al. (2013) fed conventional corn silage or BMR corn silage with fair quality or high quality alfalfa hay to the early lactating dairy cows and reported similar rumen pH, total VFA, acetate, propionate, butyrate and acetate: propionate ratio while fed conventional or BMR corn silage. However, Oba and Allen (2000), Taylor and Allen (2005) and Gorniak et al. (2014) recently found a reduced mean ruminal pH when feeding BMR silage compared to conventional silage.

CONCLUSIONS

Whole-plant corn harvested as silage is a key ration component in many diets fed to dairy cattle, and its use continues to increase in lactating dairy cattle diets. There are numerous kinds of corn hybrids available in the U.S. market to use as silage in dairy cow rations including brown midrib, leafy, floury, waxy, high lysine, and high oil hybrids. Corn hybrid selection is an important management decision in silage production to feed the dairy cows as silage yield and quality can differ greatly among different hybrids. Although past research has not shown a stable rise in milk production or DMI from feeding a particular corn silage hybrid, improved corn silage hybrids are introduced to the marketplace every year. With release of new corn hybrids, it is essential to evaluate their agronomic traits, as well as, their response on dairy cattle performance. In this research, we evaluated the production performance of early lactating cows fed on diets differ in corn silage hybrids. Crude protein content of LF$_1$ corn silage was higher than LF$_2$ and Starchy silage. Starch content was higher for Starchy corn silage compared to LF$_1$ and LF$_2$ silage. The calculation of digestible NDF per unit of DM in the TMR was lower for the control Starchy than LF$_1$ and LF$_2$ (14.0%, 15.5, and 17.9% DM). LF$_1$ and LF$_2$ hybrids supply more digestible fiber than the Starchy hybrid. Growing year affected vomitoxin concentrations on silage and may have influenced dairy cow performance. Dry matter intake, milk yield, fat yield, protein yield and 3.5% FCM yield were similar for cows fed different corn hybrid silage TMR's. Lower ruminal pH and acetate molar % and higher propionate molar % were reported with Starchy corn hybrid silage compared to LF$_1$ and LF$_2$ corn silage but similar ruminal NH_3-N content across the experimental diets. This study demonstrates that a lower starch, higher digestible fiber (DNDF) corn silage diet can support similar milk production compared to lactating cows fed a higher starch, lower digestible fiber (dNDF) diet.

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Table 3.1. Climatic conditions during the 2012 and 2013 corn crop growing seasons[1]

Months and years	Temperature, °C		Precipitation, mm	
	Mean	Deviation[2]	Total	Deviation[2]
April, 2012	9.4	3.0	70.4	14.1
May, 2012	15.6	2.2	176.3	96.3
June, 2012	20.6	1.8	40.4	-69.8
July, 2012	25.0	3.7	35.6	-47.6
August, 2012	20.0	-0.1	63.0	-13.0
September, 2012	15.0	0.1	18.5	-61.9
October, 2012	6.1	-1.5	64.8	14.3
November, 2012	0.6	1.4	11.4	-10.8
April, 2013	1.1	-5.5	66.3	8.9
May, 2013	12.8	-0.6	77.5	-4.7
June, 2013	18.3	-0.5	149.4	39.7
July, 2013	21.1	-0.3	91.9	12.3
August, 2013	21.1	1.1	38.9	-37.6
September, 2013	18.3	3.4	66.8	-11.9
October, 2013	7.8	0.2	58.4	9.3
November, 2013	-1.7	-0.9	10.2	-11.0

[1] Data collected from a weather station located at South Dakota State University approximately 3 km from the plots.

[2] Deviation = actual minus 30 year monthly average.

Table 3.2. Ingredient composition of experimental diets

Diet Ingredients	Experimental Diets[1]		
	Starchy	LF_1	LF_2
Dekalb blend corn silage	48.00	0.00	0.00
Masters Choice 527 corn silage	0.00	48.00	0.00
Masters Choice 5250 corn silage	0.00	0.00	48.00
Alfalfa hay	15.87	15.87	15.87
Ground corn	11.61	11.61	11.61
Soybean meal	0.97	0.97	0.97
Distillers grain	6.77	6.77	6.77
Corn gluten meal	1.39	1.39	1.39
Whole cotton seed	7.74	7.74	7.74
Blood meal	0.35	0.35	0.35
Soy Best® PEARL™	2.90	2.90	2.90
Meti PEARL™	0.11	0.11	0.11
Lysi PEARL™	0.15	0.15	0.15
Urea	0.48	0.48	0.48
Energy booster 100™	0.77	0.77	0.77
Limestone	1.43	1.43	1.43
Sodium Phosphate monohydrate	0.23	0.23	0.23
Sodium bicarbonate	0.28	0.28	0.28
Magnesium oxide	0.09	0.09	0.09
Potassium magnesium sulfate	0.19	0.19	0.19
Potassium chloride white	0.10	0.10	0.10
Salt white	0.35	0.35	0.35
Sel-Plex® 2000[2]	0.01	0.01	0.01
Mineral vitamin premix[3]	0.19	0.19	0.19
Total	100.00	100.00	100.00

[1] Starchy = diet with Dekalb blend corn silage, LF1 = diet with Masters Choice 527 corn silage, LF2 = diet with Masters Choice 5250 corn silage

[2] Mixture of organic selenium yeast and brewers dried yeast

[3] 10% magnesium, 2.5% zinc, 1.9% manganese, 325 mg/kg cobalt, 5,830 mg/kg copper, 325 mg/kg iodine, 1,515 mg/kg selenium, 544.32 KIU/kg vitamin A, 186.86 KIU/kg vitamin D3, 2.18 KIU/kg vitamin E.

Table 3.3. Nutrient composition of individual forages, feed ingredients, grain mix and experimental diets

Nutrient Composition	GC[1]	BM[2]	WCS[3]	CGM[4]	DG[5]	SBM[6]	SBP[7]	GM[8]	AH[9]	Corn Silage[10]			TMR[11]		
										Starchy	LF$_1$	LF$_2$	Starchy	LF$_1$	LF$_2$
DM%	89.34	90.91	92.01	91.23	90.49	89.97	90.16	90.21	86.34	37.98	39.35	42.10	53.91	55.28	57.71
--% of DM unless noted--															
CP	9.30	104.73	24.08	73.39	32.84	52.52	49.48	25.48	21.04	8.02^{b}	9.35^{a}	8.28^{b}	17.70^{b}	18.32^{a}	18.31^{a}
SP, % of CP	-	-	-	10.57	19.90	-	-	33.94	33.61	53.75^{a}	51.68^{ab}	48.09^{b}	40.64^{a}	39.46^{ab}	38.19^{b}
NDF	-	-	44.93		29.60	-	-	17.97	42.09	36.29	38.15	37.78	28.40^{b}	30.27^{b}	32.74^{a}
ADF	-	-	34.25	4.99	13.65	-	-	15.27	32.83	21.48^{f}	22.57^{ef}	23.10^{e}	19.14^{b}	20.28^{ab}	21.51^{a}
Lignin	-	-	-	-	-	-	-	-	6.80	1.80^{b}	2.19^{a}	2.41^{a}	2.72^{c}	3.22^{b}	3.81^{a}
Starch	70.59	-	-	13.97	7.79	-	-	24.63	-	37.04^{a}	32.35^{b}	33.29^{ab}	26.30^{a}	23.47^{b}	23.61^{b}
NFC	-	-	-	-	24.69	-	-	38.24	28.45	49.82^{a}	46.66^{b}	47.44^{a}	43.00^{a}	40.65^{b}	38.64^{b}
NE$_L$, Mcal/kg	2.01	-	-	-	-	1.90	-	-	1.43	1.72^{e}	1.68^{ef}	1.65^{f}	1.76^{a}	1.74^{ab}	1.70^{b}
Sugar	1.71	-	-	-	-	9.34	-	-	4.58	0.25^{b}	0.93^{a}	0.99^{a}	1.86^{b}	2.68^{a}	2.30^{a}
EE	3.62	-	-	2.40	9.84	-	6.17	9.33	1.04	2.69	2.45	2.51	4.76	4.73	4.84
Ash	-	-	-	-	4.93	-	-	11.59	9.99	3.84^{b}	4.41^{a}	4.89^{a}	7.18	7.20	7.04
IVDMD	-	-	-	-	-	-	-	-	67.67	72.21^{ef}	73.16^{e}	71.69^{f}	81.14^{a}	79.10^{b}	78.57^{b}
NDFD[12]	-	-	-	-	-	-	-	-	35.77	49.05	51.72	48.08	49.17^{c}	51.34^{b}	54.82^{a}
Ca	-	0.04	0.15	0.04	0.04	0.30	0.32	1.55	1.41	0.23^{b}	0.27^{a}	0.26^{ab}	0.85	0.88	0.84
P	0.25	0.12	0.68	0.46	0.70	0.71	0.59	0.61	0.29	0.21^{b}	0.25^{a}	0.26^{a}	0.36^{b}	0.39^{a}	0.40^{a}
Mg	0.12	0.02	0.42	0.05	0.31	0.30	0.27	0.41	0.42	0.20^{c}	0.23^{b}	0.26^{a}	0.30^{c}	0.32^{b}	0.35^{a}
K	-	0.39	1.25	0.16	1.03	-	2.02	1.08	1.88	0.74^{b}	0.94^{a}	0.85^{a}	1.11^{b}	1.21^{a}	1.21^{a}
Na	0.07	0.23	0.01	0.03	0.20	0.01	-	0.78	0.13	0.03	0.03	0.03	0.28^{b}	0.28^{ab}	0.29^{a}
Cl	-	-	-	-	-	-	-	0.80	0.64	0.19^{b}	0.38^{a}	0.40^{a}	0.53^{b}	0.61^{a}	0.63^{a}
S	0.09	0.45	0.28	0.97	0.61	0.41	0.39	0.47	0.25	0.06^{b}	0.08^{a}	0.09^{a}	0.28	0.28	0.30
pH, value	-	-	-	-	-	-	-	-	-	4.03^{b}	4.20^{a}	4.16^{ab}	-	-	-
Lactic acid	-	-	-	-	-	-	-	-	-	5.43^{a}	3.72^{b}	3.40^{b}	-	-	-

Acetic acid	-	-	-	-	-	-	-	-	-	1.91^{ef}	2.09^{e}	1.19^{f}	-	-	-
Vomitoxin, ppm	-	-	-	-	-	-	-	-	-	0.60^{b}	1.45^{a}	1.56^{a}	-	-	-

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] GC = ground corn; [2] BM = blood meal; [3] WCS = whole cotton seed; [4] CGM = corn gluten meal; [5] DG = distillers grain; [6] SBM = soybean meal; [7] SBP = soybest pearl; [8] GM = grain mix; [9] AH = alfalfa hay

[10] Starchy = Dekalb blend corn silage, LF$_1$ = Masters Choice 527 corn silage, LF$_2$ = Masters Choice 5250 corn silage

[11] Starchy = TMR with Dekalb blend corn silage, LF$_1$ = TMR with Masters Choice 527 corn silage, LF$_2$ = TMR with Masters Choice 5250 corn silage

[12] In vitro neutral detergent digestibility for 30 h

Table 3.4. Nutrient composition of experimental corn silages[1]

Nutrient composition	Experimental corn silages[2]			SEM
	Starchy	LF_1	LF_2	
CP	7.41^{c}	8.67^{a}	8.30^{b}	0.13
Available CP	6.75^{c}	7.99^{a}	7.61^{b}	0.12
SP	60.33^{a}	53.81^{b}	53.25^{b}	1.18
NDICP	0.48^{b}	0.60^{a}	0.69^{a}	0.03
ADICP	0.66	0.67	0.69	0.02
NDF	38.30^{ab}	38.06^{b}	39.18^{a}	0.51
uNDF30	24.57	23.91	24.59	0.43
uNDF120	11.14^{b}	11.53^{b}	12.50^{a}	0.19
uNDF240	10.69^{b}	11.28^{b}	11.86^{a}	0.27
TTNDFD	41.63	40.58	39.63	0.67
Dynamic NDF kd	4.41	4.39	4.31	0.10
Starch	35.90^{a}	33.68^{b}	33.34^{b}	0.63
Soluble Starch	34.29^{b}	39.89^{a}	35.61^{ab}	1.62
isSD7	68.39^{c}	77.85^{a}	73.01^{b}	1.22
Sugar	1.06^{b}	2.23^{a}	2.07^{a}	0.20
Fat	2.47	2.46	2.45	0.05
Lignin	2.08	2.17	2.50	0.16
Ash	4.38	4.54	4.35	0.08
pH	4.67^{b}	5.17^{a}	5.19^{a}	0.06
Lactic acid	5.23^{a}	2.68^{b}	2.36^{b}	0.34
Acetic acid	2.27	2.64	2.34	0.22
Ammonia	0.07^{b}	0.10^{a}	0.09^{a}	0.00

[a,b] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] analyzed in Rock River Laboratory, Inc., Watertown, WI

[2] Starchy = Dekalb blend corn silage, LF_1 = Masers Choice 527 corn silage, LF_2 = Masters Choice 5250 corn silage

Table 3.5. Relative particle size (%) of experimental TMR measured by Penn State Particle Size Separator (PSPS) on an as fed basis

PSPS screen size (mm)	Relative particle size (%)[2]			SEM	Recommended[1]
	Starchy	LF_1	LF_2		
Upper Sieve (>19.00)	4.84^{b}	6.36^{a}	6.35^{a}	0.34	2.00 - 8.00
Middle Sieve (19.00 – 8.00)	42.94^{ab}	44.10^{a}	41.34^{b}	0.65	30.00 - 50.00
Lower Sieve (8.00 – 1.18)	35.65^{ef}	34.73^{f}	35.88^{e}	0.47	30.00 - 50.00
Bottom Pan (<1.18)	16.57^{a}	14.81^{b}	16.43^{a}	0.44	< 20.00

[a,b] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] Adapted from Heinrichs and Kononoff (2002)

[2] Starchy = TMR with Dekalb blend corn silage, LF_1 = TMR with Masters Choice 527 corn silage, LF_2 = TMR with Masters Choice 5250 corn silage

Table 3.6. Dry matter intake, milk yield and milk composition, feed efficiency, body weight and body condition score of cows fed experimental diets differing in corn silage hybrids

Items	Experimental Diets[1]			SEM
	Starchy	LF_1	LF_2	
DMI, kg/d	22.90	23.50	22.43	0.78
Milk, kg/d	35.61	34.84	36.10	1.18
Fat, %	4.17	3.94	3.71	0.21
Fat Yield, kg/d	1.47	1.36	1.34	0.57
Protein, %	3.12	3.09	3.03	0.08
Protein Yield, kg/d	1.12	1.07	1.10	0.06
SCC, 10^3 cells/mL	4.57	4.75	4.64	0.16
Lactose, %	4.93	4.92	4.92	0.04
SNF, %	8.96	8.92	8.85	0.07
MUN, mg/dL	13.64^b	14.98^a	15.00^a	0.54
3.5 % FCM,[2] kg/d	38.68	36.46	37.59	1.41
ECM,[3] kg/d	38.21	36.13	38.10	1.42
BW change, kg/d	-0.10	-0.06	-0.08	0.04
Avg. BW, kg	646.66	647.69	647.83	7.95
BCS change/d	-0.05	-0.04	-0.05	0.04
FE, Milk/DMI	1.60	1.52	1.68	0.08
3.5% FCM FE	1.79	1.61	1.67	0.07

[a,b] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] Starchy = TMR with Dekalb blend corn silage, LF_1 = TMR with Masters Choice 527 corn silage, LF_2 = TMR with Masters Choice 5250 corn silage

[2] 3.5% FCM = (0.4324 × milk yield) + (16.216 × fat yield)

[3] ECM = (0.327 × milk yield) + (12.95 × fat yield) + (7.20 × protein yield)

Table 3.7. Ruminal pH, ammonia and volatile fatty acids composition of cows fed experimental diets differing in corn silage hybrids

Items	Experimental diets[1]			SEM
	Starchy	LF_1	LF_2	
pH	6.31^c	6.69^a	6.50^b	0.08
NH_3-N, mg/dL	8.60	9.30	10.28	0.96
Total VFA, mmol/L	91.84^a	72.33^b	86.54^{ab}	6.21
----------------------------mmol/100mmol of total VFA-----------------------------				
Acetate	59.49^b	63.77^a	62.44^a	0.95
Propionate	26.07^a	21.03^b	23.10^b	0.87
Isobutyrate	0.58	0.59	0.55	0.05
Butyrate	10.88	11.88	11.30	0.57
Isovalerate	1.35^a	1.09^{ab}	1.00^b	0.13
Valerate	1.63	1.67	1.64	0.09
Ace:Prop	2.32^b	3.10^a	2.81^a	0.12
Ace, Buty:Prop	2.74^b	3.67^a	3.32^a	0.14

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] Starchy = TMR with Dekalb blend corn silage, LF_1 = TMR with Masters Choice 527 corn silage, LF_2 = TMR with Masters Choice 5250 corn silage

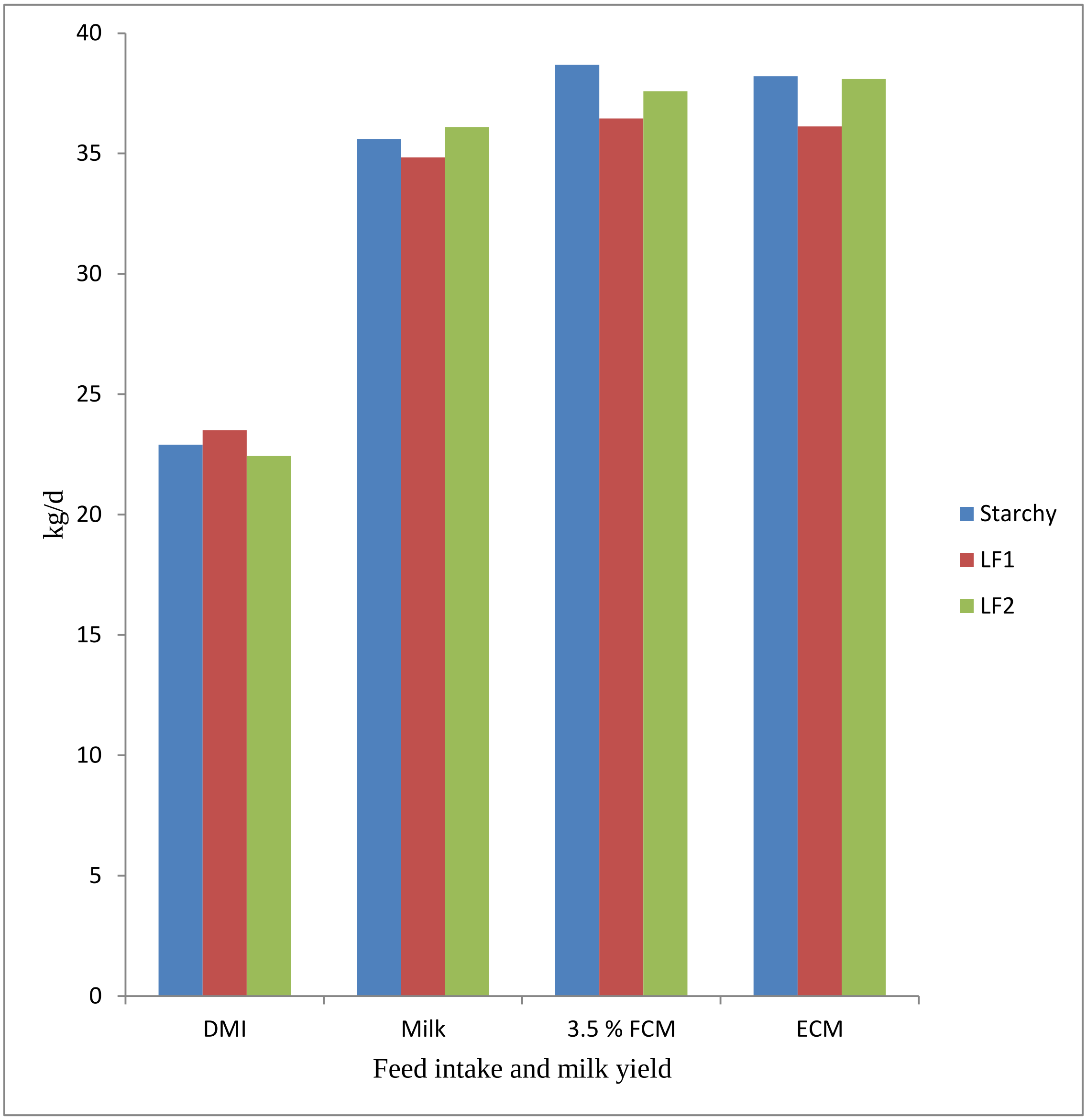

Figure 3.1. Feed intake and milk yields of cows when fed with Starchy (Dekalb blend), LF_1 (Masters Choice 527), or LF_2 (Masters Choice 5250) corn silage based TMR

CHAPTER 4

FORAGE YIELD, NUTRIENTS, AND DIGESTIBILITY WHEN INTERCROPPING VINING SOYBEAN WITH BROWN MIDRIB GRAZING CORN AT DIFFERENT SEEDING RATIOS

ABSTRACT

The production of forage blends resulting from the intercropping of corn and soybean at planting has the potential to yield greater quantities of digestible nutrients to meet the nutrient requirements of lactating dairy cows. A field plot experiment was conducted to measure forage yield, nutrient concentration and digestibility when intercropping Vining soybean line and BMR grazing corn at different seeding ratios. A randomized complete block design (RCBD) with five different seeding ratios [100:0 (T1); 67:33 (T2); 50:50 (T3); 33:67 (T4), and 0:100 (T5) of Vining soybean line and BMR grazing corn (Masters Choice Mastergraze)] with three replicates was used to determine the optimal intercropping seeding rates. Forage was hand harvested 97 d after planting during the 2014 growing season, inoculated, packed into plastic buckets, weighed, and ensiled for 0, 60, or 90 d. Buckets were then re-weighed, opened, and samples of ensiled forage collected. Fresh (0), 60 and 90 d ensiled forage samples were submitted to a commercial laboratory (Analab, Inc., Fulton, IL) for nutrient analysis. Fresh biomass yield was lowest ($P < 0.05$) for T1 (all Vining soybean) compared to other ratios of Vining soybean and BMR grazing corn (40.7, 78.0, 75.6, 75.5 and 80.9 T/ha for T1, T2, T3, T4, and T5, respectively). Fresh DM yield was greater ($P < 0.05$) for T2 and T3 compared to T1 and T5 with T4 being intermediate (16.5, 22.0, 21.1, 20.2, and 18.7 T/ha for T1, T2, T3, T4,

and T5 respectively). Digestible DM yield was greater (*P* < 0.05) for intercropping treatments (T2, T3, and T4) compared to monocropping Vining soybean (T1) with monocropping BMR grazing corn (T5) being intermediate and similar (12.4, 15.4, 14.9, 14.1 and 13.3 T/ha for T1, T2, T3, T4, and T5 respectively). Fresh CP yield was greatest (*P* < 0.05) for T1 compared to other treatments and T2 greater (*P* < 0.05) than T4, and T5 with T3 being intermediate and similar (3.94, 2.55, 2.26, 1.95, and 1.15 T/ha for T1, T2, T3, T4, and T5 respectively). Fresh digestible fiber yield (dNDF) was lower (*P* < 0.05) for monocropping Vining soybean (T1) compared to rest of the Vining soybean and BMR grazing corn seeding ratios (3.45, 6.12, 6.10, 6.10, and 6.41 T/ha for T1, T2, T3, T4, and T5 respectively). Fresh starch yield was lowest (*P* < 0.05) for T1 compared to other treatments where T3 is greater than T4, and T5 with T2 being intermediate and similar (1.17, 2.16, 2.34, 2.07, and 2.05 T/ha for T1, T2, T3, T4, and T5 respectively). Milk yield Ton/ha was greater (*P* < 0.05) for T2 and T3 compared to T1 and T5 with T3 being intermediate and similar with T2, T3, and T5 (40.01, 54.25, 53.91, 49.48, and 45.21 Ton/ha respectively). The CP content of the 90 d ensiled forage was greater for T1 compared to T5 with T2, T3, and T4 being the intermediate but not similar with T1 and T5 (25.07, 12.00, 10.38, 9.55, 5.56% CP for T1, T2, T3, T4, and T5 respectively). The CP content of forage increased with increasing Vining soybean seed proportion but decrease with increasing BMR grazing corn seed proportion in intercropping system. The increasing concentration of lactic acid from 60 to 90 d confirmed that we need to ensile forage at least for 90 d before feeding to the cows. The intercropping of Vining soybean and BMR grazing corn at a seed ratio of 67:33 holds great potential for increasing the production of quality and nutritious forage blends to meet the nutrient requirements of lactating dairy cows.

Key words: BMR grazing corn, vining soybean, forage yield

INTRODUCTION

Intercropping is a technique to boost food and forage yield, while conserving the land under cultivation. However, in recent crop production systems, the management practices used by crop producers to achieve higher productivity are improving. The most popular of these methods include increasing the efficiency of natural resources, such as water, nutrients, land surface, sunlight, and atmospheric carbon dioxide (Eslamizadeh et al., 2015). Intercropping is an improved management method of crop production which leads to efficient use of available resources. Intercropping refers to the combined growing of two or more plant species in a given time and place (Vandermeer, 1989).

The corn soybean cropping systems that dominate the upper Midwest are among the most productive in the world and contribute significantly to making the United States the world’s largest producer of corn and soybeans (U.S. Department of Agriculture, 2015). Intercropping is being encouraged as an improved approach to farming. However, it has been in a less used practice because of the difficulties of planting and harvesting (Martin et al., 1987). Intercropping involves competition for sun light, moisture and nutrients. It also restricts the herbicide options and complicates the cultivation. However, the intercrop usually benefits from increased light interception, better root contact with more soil, increased microbial activity and can act as a barrier to pests and weeds of the other crop. There is also evidence that suggests intercropping may benefit a non-legume which needs nitrogen if the other crop is a legume, since legumes will fix nitrogen in the soil. There is a potential to increase corn silage protein concentration by intercropping corn and soybean. Usually, the relatively small increase in protein concentration with corn/soybean intercropping will likely not offset the forage yield decrease compared to monocrop corn, especially given the management difficulties that may be encountered (Carter et al., 1991). Intercropping increased forage protein concentration by 1to 2 units, but reduced total forage yields by 5 to 10×, compared to monoculture corn for forage (Carter et al., 1991).

Corn is considered major forage crop for intensive dairy farming in North America due to its high DM yield and energy content (Núñez et al., 2003). Despite of that, corn has very low CP content ranging from 7.4 to 9.5% (Sanchez et al., 2010) and high NDF concentration ranging from 44.7 to 63.3% (Núñez et al., 2001), which may limit the potential forage intake by dairy cattle when NDF exceed 55% (Van Soest, 1965). This situation enforced researchers to find innovative idea to improve forage quality without losing DM yield. In order to improve forage quality, intercropping of corn and legumes have been evaluated, and reported not only similar total DM yield but also an increase in CP concentration from 1.9 to 2.7% (Herbert et al., 1984; Geren et al., 2008) and in CP yields per hectare by13.0 to 37.8% (Geren et al., 2008; Javanmard et al., 2009). Total NDF was reduced by 12.4 to 14.6% (Javanmard et al., 2009) and ADF was reduced by 7.5 to 7.7 % (Murphy et al., 1984; Demirel et al., 2009) in intercropped corn and legumes compared to mono-cropped corn.

In intercropping systems, corn represents a good alternative due to its strong yield response resulting from the border-row effect (Cruse, 2008). Soybean might be a good option for intercropping systems because of its high quality and high nutrient yields potential, especially when harvested at the beginning of the pod maturation stage (R_7). At R_7 stage, Reta et al. (2008) reported CP, ADF, and NDF concentrations of 24.6, 25.5 and 31.9%, respectively. We hypothesized that intercropping of Vining soybean and BMR grazing corn would increase total forage yield, the CP concentration of silage which help to cut down part of proteins supplements purchased by dairy farmers.

OBJECTIVES

The objectives of this study were to compare the fresh, DM and nutrient yields of forage produced from Vining soybean and BMR grazing corn intercropping or monocropping at different seeding ratios and compare nutrients composition of forage ensiled 0, 60 and 90 d after harvesting.

MATERIALS AND METHODS

The research was conducted on the South Dakota State University, Agronomy farm during the 2014 crop growing season.

Field preparation

Soil preparation consisted of plowing, disking, leveling and layout. Field was fertilized according to soil test recommendation, but no herbicides or pesticides were used. A soil sample was taken before planting the crop and after harvesting the crop to estimate the nutrition status of soil during the research period. Total of 15 plots having equal areas of 20.9 m^2 (4.57m × 4.57 m) were prepared for applying the treatments. Similar agronomical practices were provided to all plots while producing the different forage blends.

Corn and soybean varieties

BMR grazing corn (Masters Choice Mastergraze) is a conventional organic corn hybrid famous for best quality BMR forage. It has the ability to be grazed and harvested during summer, fall and winter with the potential to produce DM up to 11.21 T/ha in 7 to 8 wk with ideal growing conditions. BMR grazing corn qualities include 20 to 30% higher digestibility, 15 to 20% protein potential, low lignin, sweet and palatable due to a high sugar content (Masters Choice Seed Corn, Anna, IL).

Vining soybean line was developed by a soybean breeder at South Dakota State University through intensive selection process from wild soybeans (*Glycine soja*). Growth is an indeterminate type which climbs the corn plant if planted together. Preliminary research showed very good potential for the forage soybean to increase CP content of forage blends (Plant Science Department, South Dakota State University).

Experimental design and treatments

A field plot experiment was conducted to measure forage yield, nutrient concentration and digestibility when intercropping Vining soybean line with BMR grazing corn at different seeding ratios. A randomized complete block design (RCBD) with five different seeding ratios [100:0 (T1); 67:33 (T2); 50:50 (T3); 33:67 (T4), and 0:100 (T5) of Vining soybean line and BMR grazing corn] with three replicates was used to determine the optimal intercropping seeding ratios. We used BMR grazing corn at 86,487 seeds/ha and Vining soybean line at 358,302 seeds/ha to calculate the total counts of corn and soybean seeds respectively required in the treatment per plot. Seeds of corn and soybean were hand planted with distance between the rows of 45.72 cm.

Weeding, harvesting, ensiling, and sampling

Weeds were removed manually 3 times during the cropping season at 25, 50 and 75 d after planting and no irrigation was provided. Forage was hand harvested 97 d after planting, excluding the boarder rows, and fresh biomass yield was recorded. After wilting about 24 hours, plants were chopped with a locally made shredder, treated with *lactobacillus* inoculant (Silo-King® Plus, Agriking Inc., Fulton, IL) at recommended rate, packed into plastic buckets, weighed, and ensiled for 0, 60, or 90 d. Buckets were then re-weighed, opened, and samples of forage collected.

Sample analyses

Fresh (0), 60, and 90 d ensiled forage samples were analyzed for DM, CP, SP, ADF, NDF,ADIP, NDIP, Starch, NFC, NE_L, 6-C Sugar, EE, Nitrates, IVDMD, NDFD30, Lignin, Ash, NH_3-N, pH, Lactic acid, acetic acid, Butyric acid, Na, Mg, P, S, K, Ca, Cl, Mn, Fe, Cu and Zn (Analab, Inc., Fulton, IL). AOAC (2006) was used to analyze DM (935.29), CP (990.03), SP (Krishnamoorthy et al., 1982), ADF (973.18), NDF (2002.04), ADIP (Goering and Van Soest, 1970; Goering et al., 1972), NDIP (2002.04 minus sulfite and 976.06), Starch (996.11, enzymatic method analyzed on RFA using Glucose Trinder), NFC (100- NDF – CP – Fat – EE), NE_L (NRC, 2001), 6-C Sugar (Ethanol extract, HPLC with ELSD), EE (920.39), Nitrates (968.07), IVDMD (ANKOM technology -08/05), NDFD30 (ANKOM technology method 3), Lignin (973.18), Ash (942.05), NH_3-N (University of Wisconsin Extension SKU:A3769, MAP 4.3 adapted from USEPA 351.2 and ISO 11732), pH (981.12), Lactic acid (LC-GC Vol. 11 No. 10), Acetic Acid (LC-GC Vol. 11 No. 10), Butyric Acid (LC-GC Vol. 11 No. 10) and Minerals (Ca, P, Mg, K, Na: 985.01; S: 923.01; Cl: 915.01; Mn, Fe, Cu, ZN:985.01).

Estimation of land equivalent ratio

The ratio of area needed under sole cropping to that of intercropping at the same management level to produce an equivalent yield (Mead and Willey, 1980). Land equivalent ratio (LER), which is often considered as an indicator of intercropping benefit. The value of LER = 1 means the amount of land required for soybean and corn grown together is the same as that for soybean and corn grown in pure stand and there is no advantage to intercropping over pure cropping. LER >1 shows an advantage to intercropping, while numbers below 1 shows a disadvantage to intercropping over pure cropping. In order to study the performance of the intercropping, the following equation was used:

$$LER = (Y_{ic}/Y_{mc}) + (Y_{is}/Y_{ms})$$

Where, Y_{mc} and Y_{ms} are the sole crop yield of corn and soybean, respectively, Y_{ic} is the intercrop yield of corn, and Y_{is} is the intercrop yield of soybean.

Estimation of total nitrogen accumulated by the crop

Total nitrogen accumulated by the crops (T/ha) can be calculated as follows:

$$\text{Total N} = \Sigma\,(\text{DMY} \times \text{N}\ \%)$$

Where DMY is the yield of DM (T/ha) and N is the concentration of nitrogen in plant. Crude protein content of forage was used to calculate total nitrogen content. Once DMY per ha was multiplied by nitrogen percentage, we can get total nitrogen uptake by treatment forage on per ha basis.

Net return

$$\text{Net return (\$/ha)} = GI - (S + Mc + L + C + R + CI + Mi + I)$$

Where GI is gross income ($/ha), S is seed costs ($/ha), Mc is machinery expenses ($/ha), L is labor cost ($/ha), C is compost/manure cost ($/ha), and, R is rental land cost ($/ha), CI is crop insurance cost ($/ha), Mi is miscellaneous cost ($/ha), and I is interest on variable cost ($/ha).

Price of corn and soybean silage from FeedVal 2012 (Cabrera et al., 2015) was used to estimate gross income from forage blends. The prices of 35% DM corn silage and soybean silage (estimated through price of high quality hay), were $48.56 and $87.36 per metric ton, respectively for month of January, 2015. Proportion of corn and soybean on forage blend were estimated based on seeding ratios to calculate total gross income. Total cost of forage production was calculated by using cost estimates formula for Iowa State developed by Plastina (2016). Total cost of forage blends production ($1743.99/ha) includes seed cost ($320.84/ha), machinery cost ($345.95/ha), labor cost $172.97/ha), compost cost ($160.62/ha), rental land cost ($ 657.30/ha), crop insurance ($30.15/ha), miscellaneous ($24.71/ha), and interest on variable cost ($31.46/ha).

Statistical analysis

Statistical analysis of all data were performed by using the PROC MIXED procedure of SAS subjected to least squares ANOVA (SAS Institute Inc., Cary, NC, Version 9.4) for a randomized complete block design (Steel and Torrie, 1980). Data were tested for heterogeneity of variances and statistical significance was declared at $P \leq 0.05$.

Model used for this experiment was as follows:

$Y_{ij} = \mu + T_i + B_j + e_{ij}$

Where,

Y_{ij} is the dependent variable

μ is the overall mean

T_i is the i_{th} treatment effect (i = 1, 2,………5)

B_j is the j^{th} block effect (j = 1,2,3)

e^{ij} is the error term

RESULTS AND DISCUSSION

Temperature and rainfall patterns of crop growing season

The 2014 growing season was normal in terms of temperature, but received very high rainfall (Table 4.1) while compared to the average temperature and precipitation for past 30 years. High soil moisture may affect growth and nutrient content of whole plant silage.

Nutrient yields of forage when ensiled for 0, 60 or 90 d

Nutrient yields (T/ha) of corn and soybean sown as monocropping or intercropping at various seeding ratios ensiled for 0, 60 or 90 d after harvesting are presented in Table 4.2. Total fresh biomass and DM yield were 70.14 and 19.72 T/ha, respectively, at 0 d of ensiling (harvest d). Total digestible dry matter (DDM) yield (14.02 T/ha) was similar ($P > 0.05$) among 0, 60 and 90 d of ensiling. Total CP yield (2.37 T/ha), NDF yield (9.56 T/ha), and digestible NDF yield (5.64 T/ha) on DM basis was similar ($P > 0.05$) among 0, 60 and 90 d of ensiling. Starch yield was greater ($P < 0.05$) when ensiled for 0 d (2.67 T/ha) compared to 60 (1.81 T/ha) and 90 d (1.39 T/ha) of ensiling on DM basis. Decreasing starch value might be because of rapid anaerobic fermentation of starch during ensiling process. Similarly NFC yield was lower ($P < 0.05$) for 60 d (5.78 T/ha) and 90 d (6.07 T/ha) compared to 0 d (7.17 T/ha) ensiling. Total NE_L yield (28569.67 Mcal/ha) was similar ($P > 0.05$) among the treatments. This indicated that ensiling process was efficient to retain the original energy content of the forage. There are some reports stating that some microbial activity also occurs during the stable phase of the ensiling process (Der Bedrosian et al., 2012). Because of the microbial activity during the first 2 to 6 wk and the possible ongoing microbial activity afterwards, ensiling duration may affect the final nutritional quality of the silage (Ali et al., 2015). Milk yield estimated through Milk2006 (Shave et al., 2006) was tended to be greater ($P < 0.10$) when ensiled for 0 d compared to 60 and 90 d (51.84, 46.57, and 47.30 milk T/ha for 0, 60, and 90 d of ensiling respectively).

Nutrient yields of forage on experimental treatments

Nutrient yields (T/ha) of forage from the experimental treatments are presented in Table 4.3 and Figure 4.1. Fresh biomass yield was lower ($P < 0.05$) for T1 compared to rest of the treatments (40.65, 78.04, 75.63, 75.53, 80.86 T/ha for T1, T2, T3, T4, and T5 respectively). However, DM yield was higher in T2 and T3 compared to T5 and T1 with T4 being intermediate (16.48, 22.04, 21.14, 20.24, and 18.72 T/ha for T1, T2, T3, T4, and T5 respectively). Dry matter loss when ensiled for 60 d was greater ($P < 0.05$) for T1 compared to rest of the treatments (5.23, 1.34, 1.22, 1.71, and 1.97 T/ha DM loss for T1, T2, T3, T4, and T5 respectively). However, DM loss when ensiled for 90 d was similar ($P > 0.05$) across the treatments (1.24 T/ha DM loss). Digestible dry matter (DDM) yield was lower ($P < 0.05$) for T1 compared to T2, T3, and T4 with T5 being intermediate (12.40, 15.44, 14.85, 14.12, and 13.27 T/ha for T1, T2, T3, T4, and T5 respectively). In contrast, CP yield was higher ($P < 0.05$) for monocropped Vining soybean (T1) compared to rest of the treatments (3.94, 2.55, 2.26, 1.95, and 1.15 T/ha for T1, T2, T3, T4, and T5 respectively). The NDF yield and DNDF yield were lower ($P < 0.05$) for monocropped Vining soybean (T1) compared to rest of the treatments (6.33, 10.89, 10.49, 10.18 and 9.94 T/ha NDF and 3.45, 6.12, 6.10, 6.10, and 6.41 T/ha NDFD for T1, T2, T3, T4, and T5 respectively). Starch yield (T/ha) was greater ($P < 0.05$) for T3 compared to T1, T4, and T5 with T2 being intermediate (1.17, 2.16, 2.34, 2.07, and 2.05 T/ha for T1, T2, T3, T4, and T5 respectively). The NFC yield was lower ($P < 0.05$) for monocropped Vining soybean (T1) compared to the rest of the treatments (4.54, 7.12, 7.00, 6.76, and 6.29 T/ha for T1, T2, T3, T4, and T5 respectively). Net energy for lactation (NE_L) yield was greater ($P < 0.05$) for T2 compared to T1, T4, and T5 with T3 being intermediate (23994, 32316, 30980, 29187, and 26369 Mcal/ha for T1, T2, T3, T4, and T5 respectively). Milk yield estimated through Milk2006 (Shaver et al., 2006) was greater ($P < 0.05$) for T2, and T3 compared to T1 (all Vining soybean), and T5 (all BMR grazing corn) with T4 being intermediate (40.01, 54.25, 53.91, 49.48, and 45.21 T/ha for T1, T2, T3, T4, and T5 respectively).

Land equivalent ratio, net return and nitrogen accumulation

Land equivalent ration, net return and nitrogen accumulation by treatment forage are presented in Table 4.4. Land equivalent ratio was greater ($P < 0.05$) for T2 compared to T1 and T5 with T3 and T4 being intermediate and similar (1.00, 1.19, 1.13, 1.05, and 1.00 LER for T1, T2, T3, T4, and T5 respectively). Thus, intercropping of Vining soybean and BMR grazing corn at 67:33 seeding ratio produced more forage yield compare to monocropping of soybean or corn on same piece of land. Net return from forage was greater ($P < 0.05$) for T1 and T2 compared to T4, and T5 with T3 being intermediate (2370.04, 2805.16, 2150.30, 1532.94, and 478.55 net profit $/ha for T1, T2, T3, T4, and T5 respectively). Nitrogen accumulation by treatment forage was greater (P

< 0.05) for T1 compared to T2, T2 compared to T5 with T3, and T4 being intermediate and similar (0.60, 0.37, 0.34, 0.31, and 0.19 T/ha for T1, T2, T3, T4, and T5 respectively).

Nutrient composition of forage when ensiled for 0, 60, or 90 d

Nutrient composition of forage ensiled for different time periods are presented in Table 4.5. DM content was higher ($P < 0.05$) when ensiled for 0 d compared to 60 and 90 d (29.33, 27.15 and 27.70 % DM for 0, 60, and 90 d ensiling respectively). About 2 % moisture was added during 60 and 90 d ensiling periods. Crude protein concentrations were similar ($P > 0.05$) across the 0, 60 and 90 d ensiling periods (12.36 % CP). However, SP concentration was higher ($P < 0.05$) for 90 d ensiling compared to 0 and 60 d ensiling (34.69, 44.57, 49.16% SP for 0, 60, and 90 d ensiling respectively). The ADF concentration was higher ($P < 0.05$) for 60 and 90 d compared to 0 d (29.64, 32.22, and 31.66 % ADF for 0, 60, and 90 d ensiling respectively). The NDF concentration was higher ($P < 0.05$) for 60 d compared to 0 and 90 d (45.71, 50.4, and 48.35 % NDF for 0, 60, and 90 d ensiling respectively). The ADIP and NDIP concentrations were lower ($P < 0.05$) for 90 d ensiling compared to 0 and 60 d ensiling (0.88, 0.83, and 0.66 % ADIP; and 2.18, 2.01, and 1.43 % NDIP for 0, 60, and 90 d ensiling respectively). Starch, NFC, sugar, NE_L, nitrates, and pH concentrations of forage were higher for 0 d ensiling compared to 60 d and 90 d ensiling (13.40, 6.94, and 6.40 % Starch; 36.19, 29.25, and 30.65% NFC; 11.29, 0.81, 0.64 % sugar; 1.50, 1.41, and 1.43 Mcal/kg NE_L; 33.93, 19.36, and 1.91ppm nitrates; and 4.56, 4.03, 3.65 pH for 0, 60, and 90 d ensiling respectively). Fat concentration was greater ($P < 0.05$) for 60 and 90 d ensiling forage compared to 0 d ensiling forage (1.95, 2.36, and 2.27 % fat for 0, 60, and 90 d ensiling respectively). The IVDMD of forage was similar (*P* > 0.05) across the d of ensiling (49.89 %). However, 30 h in vitro NDFD of forage was lower (*P* < 0.05) for 60 d compared to 0 d and 90 d (59.61, 54.88, and 61.67% NDFD for 0, 60, and 90 d ensiling respectively). Lignin concentration of forage was lower (*P* < 0.05) in 90 d ensiling compared to 0 and 60 d ensiling (4.19, 4.40, and 3.10 % lignin for 0, 60, and 90 d ensiling respectively). Ash concentration was elevated (*P* < 0.05) with ensiling d (6.56, 7.14, and 7.63 % ash for 0, 60, and 90 d ensiling respectively). The NH_3-N concentration was lower (*P* < 0.05) for 0 d compared to 60 d and 90 d ensiling (703.01, 1092.67, and 1053.73 ppm of NH_3-N for 0, 60, and 90 d ensiling respectively). Lactic acid concentration, acetic acid concentration, and lactic to acetic acid ratio of forage were greater (*P* < 0.05) for 60 d and 90 d ensiling compared to 0 d ensiling (2.11, 5.71, and 6.52 % lactic acid; 0.09, 1.23, and 1.28 % acetic acid; and 1.18, 9.06, and 7.80 lactic to acetic acid ratio for 0, 60, and 90 d ensiling respectively). Continue decreasing value of pH and increasing value of lactic acid from 0 d to 90 d indicated that ensiling 60 d was not sufficient to produce a stable quality silage. Ferraretto et al. (2015) reported that extended time in storage increased the NH_3-N content, soluble CP content, and in vitro starch digestibility in whole plant corn silage of various hybrids, maturities, and chop lengths, which is consistent with our findings. Fermentation of ensiled corn silage by lactic acid bacteria usually ends within three weeks (Jaster, 1995). On the other hand, a study reported by Ward and de Ondarza (2008) suggested that, corn silage requires at least four months for completing the fermentation process. Kleinschmit and Kung (2006) reported that a satisfactory fermentation of corn silage in mini silos requires 361 days of ensiling where the major increase in acetic acid in untreated corn silage occurred between 282 and 361 days. At anaerobic and low pH condition, *Lactobacillus buchneri* is able to convert lactic acid to acetic acid, ethanol and 1, 2 propanediol (Oude-Elferink et al., 2001). Yahaya et al. (2002) also reported that increasing ensiling time of high moisture orchardgrass would result in the excessive losses of DM, water soluble carbohydrate, hemicellulose and cellulose in the silage.

Mineral composition of forage when ensiled for 0, 60, or 90 d

Mineral composition of ensiling forage for 0, 60, or 90 d is presented in Table 4.6.There was no effect ($P > 0.05$) of ensiling d on forage concentration of Ca (0.53, 0.56, and 0.54 % Ca for 0, 60, and 90 d ensiling respectively). However, forage concentration of P and K was lower ($P < 0.05$) for 0 d ensiling compared to 60 and 90 d ensiling (0.31, 0.34, and 0.33 % P; and 1.51, 1.67, and 1.61% K for 0, 60, and 90 d ensiling respectively). At 60 d ensiling, concentrations of Mg, S, Mn, Fe and Cu in forage were maximum ($P < 0.05$) compared to 0 and 90 d ensiling. However, concentration of forage Na, Cl and Zn were elevated ($P < 0.05$) with increasing ensiling time.

Nutrient composition of forage when ensiled for 60 d

Nutrients composition of corn and soybean grown as monocropping or intercropping at various seeding ratios ensiled for 60 d are listed in Table 4.7. While ensiled for 60 d, monocropped Vining soybean (T1) has higher ($P < 0.05$) DM content compared to T5 with T3, and T4 being intermediate (38.14, 26.20, 26.46, 23.59, and 21.35 % DM for T1, T2, T3, T4 and T5 respectively). The CP concentration was higher ($P < 0.05$) for T1 compared to T5 with T3, T4 and T5 being intermediate (24.12, 12.33, 11.33, 9.66, and 6.56 % CP for T1, T2, T3, T4 and T5 respectively). The SP concentration was higher ($P < 0.05$) for T5 compared to T1 and others being intermediate. The ADF concentration was higher ($P < 0.05$) for T5 compared to the T2 and T3 with T1, and T4 being intermediate. The NDF concentration was lower ($P < 0.05$) for T1 compared to rest of the treatments. The ADICP concentration was higher ($P < 0.05$) for T1 compared to rest of the treatments while NDICP concentration was lower ($P < 0.05$) for T5 compared to other treatments. Starch concentration was similar ($P > 0.05$) for T2, T3, T4 and T5 (8.68 % starch) where starch value was not reported in monocropped Vining soybean silage (T1). NFC concentration was lower ($P < 0.05$) in T1 compared to T3, and T5 with T2, and T4 being intermediate (26.71, 29.69, 30.07, 28.83, and 30.93 % NFC for T1, T2, T3, T4 and T5 respectively). NE_L (Mcal/kg) of forage was lower ($P < 0.05$) for T5 compared to T1, T2 and T3 with T4 being intermediate. The EE concentration was higher ($P < 0.05$) for T1 compared to rest of the treatments. Sugar and nitrates concentration of forage were similar ($P < 0.05$) among the treatments. The IVDMD % was higher ($P < 0.05$) for T1 and 30 h NDFD % was higher ($P < 0.05$) for T5 compared to rest of the treatments. Lignin concentration was lower ($P < 0.05$) for T5 compared to T1 with T2, T3, and T4 being intermediate. Ash concentration, NH_3-N concentration and pH value of forage were higher ($P < 0.05$) for T1 compared to rest of the treatments. Lactic acid concentration was greater ($P < 0.05$) for T5 compared to rest of the treatments. Acetic acid concentration was higher ($P < 0.05$) for T1 and T5 compared to rest of the treatments. Lactic acid to acetic acid ratio was greater ($P < 0.05$) for T3 compared to T1 with T2, T4, and T5 being intermediate.

Nutrient composition of forage when ensiled for 90 d

Nutrients composition of BM R grazing corn and Vining soybean sown as mono-cropping or intercropping at different seeding ratios ensiled for 90 d are presented in Table 4.8. While ensiling for 90 d, T1 has higher ($P < 0.05$) DM percentage (38.16%) compared to T5 (22.13%) while T2, T3 and T4 were intermediate. The CP concentration was higher ($P < 0.05$) for T1 compared to rest of the treatments (25.07, 12.00, 10.38, 9.55, and 5.56 % CP for T1, T2, T3, T4 and T5 respectively). However, CP concentration of intercropped treatments (T2, T3, and T4 were greater ($P < 0.05$) than monocropped BMR grazing corn (T5). The SP concentration was higher ($P < 0.05$) for T5 compared to T1 and T2 with T3, and T4 being intermediate. The ADF and NDF concentration of forage were higher ($P < 0.05$) for T5 compared to rest of the treatments. The ADIP concentration was higher ($P < 0.05$) for T1 compared to rest of the treatments while NDIP concentration was lower ($P < 0.05$) for T1 and T5 compared to other treatments. Starch concentration was greater ($P < 0.05$) for T3 compared to T2, T4, and T5 while starch concentration was not detected in T1 (7.11, 9.59, 7.74, and 7.58% starch for T2, T3, T4, and T5 respectively). The NFC concentration were lower ($P < 0.05$) for T1 compared to rest of the treatments (27.65, 30.35, 31.80, 31.16, and 32.29 % NFC for T1, T2, T3, T4 and T5 respectively). The NE_L concentration (MCal/kg) was lower ($P < 0.05$) for T4 and T5 compared to T1. The EE concentration was higher ($P < 0.05$) for T1 compared to rest of the treatments. Sugar and Nitrates concentration was similar ($P > 0.05$) among the treatments. The IVDMD % was greater ($P < 0.05$) and 30 h NDFD % was lower ($P < 0.05$) for T1 compared to rest of the treatments. Lignin concentration, Ash concentration, NH_3-N concentration, and pH value were higher ($P < 0.05$) for T1 compared to rest of the treatments. Lactic acid concentration was greater ($P < 0.05$) for T5 compared to T1 and T3. Acetic acid concentration was greater ($P < 0.05$) for T1 compared to rest of the treatments. Lactic to acetic acid ratio was higher ($P < 0.05$) for T5 compared to rest of the treatments.

Mineral composition of forage when ensiled for 60 d

Mineral composition of forage when corn and soybean sown as mono-cropping or intercropping at different seeding ratios ensiled for 60 d are presented in Table 4.9. Concentration of Ca, P, K, Mg, Na, S, Mn and Cu were greater ($P < 0.05$) in monocropped soybean (T1) and decrease with increased seed proportion of BMR grazing corn (T2, T3, T4) and monocropped BMR grazing corn (T5). However, concentration of Cl and Fe were greater ($P < 0.05$) in monocropped BMR grazing corn (T5) and decrease with decrease proportion of corn seed (T4, T3, and T2) and monocropped Vining soybean (T1). The higher concentration of most of the minerals indicated that Vining soybean forage is an excellent source of minerals than corn silage for dairy cows.

Minerals composition of forage when ensiled for 90 d

Minerals of corn and soybean sown as mono-cropping or intercropping at different seeding ratios ensiled for 90 d are presented in Table 4.10. Concentration of Ca, P, K, Mg, S, Mn, Fe and Cu were greater ($P < 0.05$) in monocropped Vining soybean (T1) and decrease with increased seed proportion of corn (T2, T3, T4) and monocropped BMR grazing corn (T5). However, concentration of Cl and Zn were greater ($P < 0.05$) in monocropped BMR grazing corn (T5) and decrease with decrease proportion of corn seed

(T4, T3, and T2) and monocropped Vining soybean (T1). Report on mineral concentration of 0, 60 and 90 d ensiled forage revealed that soybean silage is a richer source of most of the minerals compared to corn silage.

CONCLUSIONS

Intercropping of Vining soybean with BMR grazing corn resulted higher DM yield compared to monocrop BMR grazing corn or monocrop Vining soybean. Concentration of forage CP increased with increasing inclusion level of soybean seeds when intercropped with corn. The optimal seeding ratio of Vining soybean to BMR grazing corn is somewhere between 67:33 and 50:50 based on DDM and Milk Ton/ha from the results of this study. The ensiling process is not completed at 60 d. Thus, studies on ensiled forage quality should be a minimum of 90 d. Silage produced from monocropped Vining soybean or intercropped with BMR grazing corn are richer sources of most minerals compared to moncropped BMR grazing corn silage. Intercropping of Vining soybean and BMR grazing corn for silage holds promised for producing highly digestible forage for dairy cattle compared to monocropping of corn or soybean.

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Table 4.1. Climatic conditions during the 2014 crop growing season[1]

Months	Temperature, °C		Precipitation, mm	
	Mean	Deviation[2]	Total	Deviation[2]
April	5.0	-1.5	44.5	-14.1
May	12.8	-0.7	814.3	730.5
June	18.9	0.0	224.0	113.2
July	19.4	-1.9	61.2	-18.9
August	20.0	0.0	73.7	-0.5
September	15.6	0.5	50.8	-28.2
October	8.9	1.4	16.8	-33.3
November	-5.0	-4.2	19.6	1.9

[1] Data collected from a weather station located at South Dakota State University approximately 3 km from the plots.

[2] Deviation = actual minus 30 year monthly average.

Table 4.2. Nutrient yields (T/ha unless noted) of forage when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios ensiled for 0, 60 or 90 days

	Days of ensiled[1]			
Yields	0	60	90	SEM
Fresh	70.14	-	-	2.91
DM[2]	19.72	-	-	0.83
DDM[3]	14.02	13.94	14.09	1.21
CP[4]	2.26	2.46	2.39	0.13
NDF[5]	9.06	10.02	9.61	0.64
DNDF[6]	5.40	5.52	5.99	0.21
Starch	2.67^{a}	1.43^{b}	1.33^{b}	0.12
NFC[7]	7.17^{a}	5.78^{b}	6.07^{b}	0.46
NE_L[8], MCal/ha	29420	28011	28278	1246.27
Milk[9]	51.84^{e}	46.57^{f}	47.30^{f}	2.20

[a,b],Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f]Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] 0 = fresh or ensiled for 0 days, 60 = ensiled for 60 days, 90 = ensiled for 90 days

[2] Dry matter; [3]Digestible dry matter; [4]Crdue protein; [5]Neutral detergent fiber; [6]Digestible neutral detergent fiber; [7]Non fiber carbohydrate; [8] Net energy for lactation estimated through NRC (2001); [9]Milk yield potential of forage estimated through MILK2006

Table 4.3. Forage and nutrient yields (T/ha unless noted) when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios

	Treatments[1]					
Yields	T1	T2	T3	T4	T5	SEM
Fresh biomass	40.65^{b}	78.04^{a}	75.63^{a}	75.53^{a}	80.86^{a}	3.29
DM[2]	16.48^{c}	22.04^{a}	21.14^{a}	20.24^{ab}	18.72^{b}	0.97
60 d DM loss	5.23^{a}	1.34^{b}	1.22^{b}	1.71^{b}	1.97^{b}	1.12
90 d DM loss	1.30	0.86	1.03	1.22	1.80	0.35
DDM[3]	12.40^{b}	15.44^{a}	14.85^{a}	14.12^{a}	13.27^{ab}	1.27
CP[4]	3.94^{a}	2.55^{b}	2.26^{bc}	1.95^{c}	1.15^{d}	0.17
NDF[5]	6.33^{b}	10.89^{a}	10.49^{a}	10.18^{a}	9.94^{a}	0.69
DNDF[6]	3.45^{b}	6.12^{a}	6.10^{a}	6.10^{a}	6.41^{a}	0.27
Starch	1.17^{c}	2.16^{ab}	2.34^{a}	2.07^{b}	2.05^{b}	0.14
NFC[7]	4.54^{b}	7.12^{a}	7.00^{a}	6.76^{a}	6.29^{a}	0.48
NE_L[8], Mcal/ha	23994^{d}	32316^{a}	30980^{ab}	29187^{bc}	26369^{cd}	1500
Milk[9]	40.01^{c}	54.25^{a}	53.91^{a}	49.48^{ab}	45.21^{bc}	2.67

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio

[2] Dry matter; [3] Digestible dry matter; [4] Crude protein; [5] Neutral detergent fiber; [6] Digestible neutral detergent fiber; [7] Non fiber carbohydrate; [8] Net energy for lactation estimated through NRC (2001); [9] Milk yield potential of forage estimated through MILK2006

Table 4.4. Land equivalent ratio, net return, and nitrogen accumulation by treatment forage when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios

	Treatments[1]					
Item	T1	T2	T3	T4	T5	SEM
Land equivalent ratio[2]	1.00^{b}	1.19^{a}	1.13^{ab}	1.05^{ab}	1.00^{b}	0.06
Net return[3], \$/ha	2370.04^{a}	2805.16^{a}	2150.30^{ab}	1532.94^{b}	478.55^{c}	275.56
N accumulation[4], T/ha	0.60^{a}	0.37^{b}	0.34^{bc}	0.31^{bc}	0.19^{c}	0.05

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio

[2] (yield of intercrop corn/yield of monocrop corn) + (yield of intercrop soybean/yield of monocrop soybean)

[3] Net return from forage

[4] Nitrogen accumulation by treatment forage

Table 4.5. Forage nutrient composition when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios ensiled for 0, 60 or 90 days

	Days of ensiled[1]			
Nutrients composition	0	60	90	SEM
DM, %	29.33^{a}	27.15^{b}	27.70^{b}	0.30
-----------------------------------% of DM unless noted-------------------------------------				
CP	11.76	12.80	12.51	0.39
SP[2], % of CP	34.69^{c}	44.57^{b}	49.16^{a}	1.01
ADF	29.64^{b}	32.22^{a}	31.66^{a}	0.31
NDF	45.71^{c}	50.4^{7a}	48.35^{b}	0.64
ADIP[3]	0.88^{a}	0.83^{a}	0.66^{b}	0.04
NDIP[4]	2.18^{a}	2.01^{a}	1.43^{b}	0.09
Starch	13.40^{a}	6.94^{b}	6.40^{b}	0.37
NFC[5]	36.19^{a}	29.25^{b}	30.65^{b}	0.66
NE_L, MCal/kg	1.50^{a}	1.41^{b}	1.43^{b}	0.02
Sugar	11.29^{a}	0.81^{b}	0.64^{b}	0.26
Fat	1.95^{b}	2.36^{a}	2.27^{a}	0.04
Nitrates, ppm	33.93^{a}	19.36^{b}	1.91^{c}	1.82
IVDMD[6]	71.27	70.78	71.63	0.34
NDFD[7]	59.61^{a}	54.88^{b}	61.67^{a}	1.14
Lignin	4.19^{a}	4.40^{a}	3.10^{b}	0.10
Ash	6.56^{c}	7.14^{b}	7.63^{a}	0.14
NH_3-N, ppm	703.01^{b}	1092.67^{a}	1053.73^{a}	50.45
pH, Scale	4.56^{a}	4.03^{b}	3.65^{c}	0.05
Lactic acid	2.11^{c}	5.71^{b}	6.52^{a}	0.16
Acetic acid	0.09^{b}	1.23^{a}	1.28^{a}	0.07
Lactic: Acetic, Ratio	1.18^{b}	9.06^{a}	7.80^{a}	2.17

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] 0 = fresh or ensiled for 0 days, 60 = ensiled for 60 days, 90 = ensiled for 90 days

[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro neutral detergent fiber digestibility for 30 h

Table 4.6. Forage mineral composition (% of DM unless noted) when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios ensiled for 0, 60 or 90 days

Minerals composition	Days of ensiled[1]			SEM
	0	60	90	
Ca	0.53	0.56	0.54	0.02
P	0.31^{b}	0.34^{a}	0.33^{a}	0.01
K	1.51^{b}	1.67^{a}	1.61^{a}	0.06
Mg	0.27^{b}	0.30^{a}	0.26^{c}	0.005
Na	0.02^{b}	0.02^{b}	0.04^{a}	0.002
Cl	0.20^{ab}	0.17^{b}	0.23^{a}	0.01
S	0.11^{c}	0.13^{a}	0.12^{b}	0.003
Mn, ppm	42.53^{b}	46.16^{a}	43.60^{ab}	1.26
Fe, ppm	299.13^{b}	388.69^{a}	266.80^{b}	21.73
Cu, ppm	5.13^{b}	6.13^{a}	5.13^{b}	0.17
Zn, ppm	24.13^{c}	26.71^{b}	28.96^{a}	0.73

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] 0 = fresh or ensiled for 0 days, 60 = ensiled for 60 days, 90 = ensiled for 90 days

Table 4.7. Forage nutrient composition when Vining soybean and BMR grazing corn sown as mono-cropping or intercropping at different seeding ratios ensiled 60 days

Nutrients composition	Treatments[1]					SEM
	T1	T2	T3	T4	T5	
DM%	38.14^{a}	26.20^{b}	26.46^{b}	23.59^{c}	21.35^{d}	0.64
--% of DM unless noted--						
CP	24.12^{a}	12.33^{b}	11.33^{b}	9.66^{b}	6.56^{c}	0.78
SP[2], % of CP	39.28^{c}	42.99^{bc}	43.52^{bc}	46.28^{b}	50.76^{a}	1.91
ADF	32.63^{ab}	30.95^{c}	31.33^{bc}	2.50^{ab}	33.67^{a}	0.58
NDF	39.24^{b}	51.24^{a}	52.06^{a}	54.86^{a}	54.95^{a}	1.23
ADIP[3]	1.71^{a}	0.72^{b}	0.68^{b}	0.62^{b}	0.44^{c}	0.06
NDIP[4]	2.50^{a}	2.34^{a}	2.14^{a}	1.92^{a}	1.18^{b}	0.18
Starch	-	8.62	9.00	8.47	8.61	0.82
NFC5	26.71^{b}	29.69^{ab}	30.07^{a}	28.83^{ab}	30.93^{a}	1.18
NE_L, Mcal/kg	1.43^{ab}	1.46^{a}	1.43^{ab}	1.41^{bc}	1.37^{c}	0.02
Sugar	0.85	1.31	1.09	0.40	0.42	0.54
EE	3.12^{a}	2.53^{b}	2.42^{bc}	2.19^{c}	1.52^{d}	0.09
Nitrates, ppm	17.89	20.78	16.67	17.44	24.00	3.18
IVDMD[6]	74.52^{a}	70.88^{b}	70.31^{b}	69.32^{b}	68.89^{b}	0.69
NDFD[7]	51.82^{b}	52.43^{b}	51.08^{b}	57.07^{ab}	62.00^{a}	1.96
Lignin	7.60^{a}	4.39^{b}	4.29^{b}	4.17^{b}	1.56^{c}	0.18
Ash	9.31^{a}	6.55^{bc}	6.25^{c}	6.37^{c}	7.21^{b}	0.29
NH_3-N, ppm	1906.59^{a}	983.83^{b}	936.25^{bc}	790.27^{c}	846.41^{bc}	95.13
pH, Scale	5.21^{a}	3.97^{b}	3.92^{b}	3.88^{b}	3.18^{c}	0.09
Lactic acid	3.45^{c}	5.89^{b}	5.92^{b}	5.76^{b}	7.55^{a}	0.30
Acetic acid	1.99^{a}	0.85^{bc}	0.54^{c}	0.99^{b}	1.81^{a}	0.14
Lactic: Acetic, Ratio	1.69^{c}	7.02^{b}	26.46^{a}	5.94^{bc}	4.19^{bc}	3.51

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio

[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro neutral detergent fiber digestibility for 30 h

Table 4.8. Forage nutrient composition when corn and soybean sown as mono-cropping or intercropping at different seeding ratios ensiled 90 days

	Treatments[1]					
Nutrients composition	T1	T2	T3	T4	T5	SEM
DM%	38.16^{a}	26.96^{b}	26.34^{b}	24.96^{bc}	22.13^{c}	0.64
---------------------------------------% of DM (Unless noted)---						
CP	25.07^{a}	12.00^{b}	10.38^{b}	9.55^{b}	5.56^{c}	0.78
SP, % of CP	47.16^{b}	45.91^{b}	48.74^{ab}	50.20^{ab}	53.79^{a}	1.91
ADF	31.03^{b}	30.82^{b}	30.74^{b}	31.81^{b}	33.89^{a}	0.58
NDF	35.97^{c}	49.73^{b}	50.29^{b}	51.41^{b}	54.36^{a}	1.23
ADIP	1.40^{a}	0.54^{b}	0.48^{bc}	0.47^{bc}	0.41^{c}	0.06
NDIP	1.17^{b}	1.86^{a}	1.56^{a}	1.48^{a}	1.06^{b}	0.18
Starch	-	7.11^{b}	9.59^{a}	7.74^{b}	7.58^{b}	0.82
NFC	27.65^{b}	30.35^{ab}	31.80^{a}	31.16^{a}	32.29^{a}	1.18
NE_L, Mcal/kg	1.48	1.46^{ab}	1.46^{ab}	1.43^{b}	1.37^{c}	0.02
Sugar	0.43	0.29	0.66	0.85	0.96	0.54
EE	3.32^{a}	2.48^{b}	2.26^{bc}	1.94^{c}	1.35^{d}	0.09
Nitrates, ppm	4.22	2.33	1.00	1.00	1.00	3.18
IVDMD	76.76^{a}	70.33^{b}	70.87^{b}	70.77^{b}	69.44^{b}	0.69
NDFD	54.27^{b}	62.83^{a}	63.00^{a}	64.88^{a}	63.39^{a}	1.96
Lignin	7.35^{a}	2.41^{b}	2.13^{bc}	1.98^{c}	1.61^{d}	0.18
Ash	9.15^{a}	7.28^{b}	6.82^{b}	7.40^{b}	7.49^{b}	0.29
NH_3-N, ppm	1972.33^{a}	940.89^{b}	885.56^{bc}	827.89^{bc}	642.00^{c}	95.13
pH, Scale	4.82^{a}	3.60^{b}	3.50^{bc}	3.31^{c}	3.00^{d}	0.09
Lactic acid	5.04^{c}	6.91^{ab}	6.40^{b}	6.82^{ab}	7.43^{a}	0.30
Acetic acid	2.63^{a}	1.08^{b}	1.09^{b}	0.98^{b}	0.64^{b}	0.14
Lactic: Acetic, Ratio	1.92^{c}	6.47^{b}	6.05^{bc}	7.10^{bc}	17.49^{a}	3.51

^{a,b,c,d}Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio

[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro neutral detergent fiber digestibility for 30 h

Table 4.9. Forage mineral composition (% of DM unless noted) when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios ensiled 60 days

Minerals composition	Treatments[1]					SEM
	T1	T2	T3	T4	T5	
Ca	1.040^{a}	0.530^{b}	0.506^{bc}	0.420^{c}	0.299^{d}	0.032
P	0.364^{a}	0.351^{ab}	0.339^{b}	0.338^{bc}	0.323^{c}	0.012
K	2.122^{a}	1.651^{b}	1.557^{b}	1.581^{bc}	1.446^{c}	0.078
Mg	0.371^{a}	0.293^{b}	0.298^{b}	0.263^{c}	0.267^{c}	0.009
Na	0.023^{a}	0.012^{b}	0.017^{ab}	0.016^{b}	0.018^{ab}	0.003
Cl	0.011^{b}	0.203^{a}	0.191^{a}	0.258^{a}	0.200^{a}	0.022
S	0.197^{a}	0.131^{b}	0.120^{bc}	0.109^{c}	0.098^{d}	0.005
Mn, ppm	77.778^{a}	44.333^{b}	42.778^{b}	37.111^{b}	28.778^{c}	2.438
Fe, ppm	376.000^{b}	365.670^{b}	356.890^{b}	379.440^{ab}	465.440^{a}	41.897
Cu, ppm	9.000^{a}	5.667^{b}	5.444^{b}	5.222^{b}	5.333^{b}	0.372
Zn, ppm	25.110	28.890	23.890	28.330	27.330	1.478

[a,b,c,d] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio

Table 4.10. Forage mineral composition (% of DM unless noted) when Vining soybean and BMR grazing corn sown as mono-cropping or intercropping at different seeding ratios ensiled 90 days

Minerals composition	Treatments[1]					SEM
	T1	T2	T3	T4	T5	
Ca	1.022^{a}	0.537^{b}	0.453^{bc}	0.423^{c}	0.258^{d}	0.0320
P	0.372^{a}	0.334^{ab}	0.324^{b}	0.318^{bc}	0.302^{c}	0.012
K	2.114^{a}	1.594^{b}	1.490^{b}	1.540^{b}	1.314^{c}	0.078
Mg	0.336^{a}	0.253^{b}	0.250^{b}	0.234^{b}	0.210^{c}	0.009
Na	0.040	0.040	0.030	0.040	0.030	0.003
Cl	0.012^{c}	0.251^{b}	0.279^{ab}	0.299^{a}	0.287^{a}	0.022
S	0.204^{a}	0.118^{b}	0.102^{b}	0.099^{b}	0.074^{c}	0.005
Mn, ppm	77.444^{a}	43.111^{b}	37.333^{b}	35.444^{b}	24.667^{c}	2.438
Fe, ppm	378.780^{a}	268.670^{ab}	210.110^{b}	274.000^{ab}	202.440^{b}	41.897
Cu, ppm	9.333^{a}	4.778^{b}	4.556^{bc}	3.667^{cd}	3.333^{d}	0.372
Zn, ppm	26.778^{c}	29.000^{bc}	26.444^{bc}	31.889^{a}	30.667^{ab}	1.478

[a,b,c,d] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio

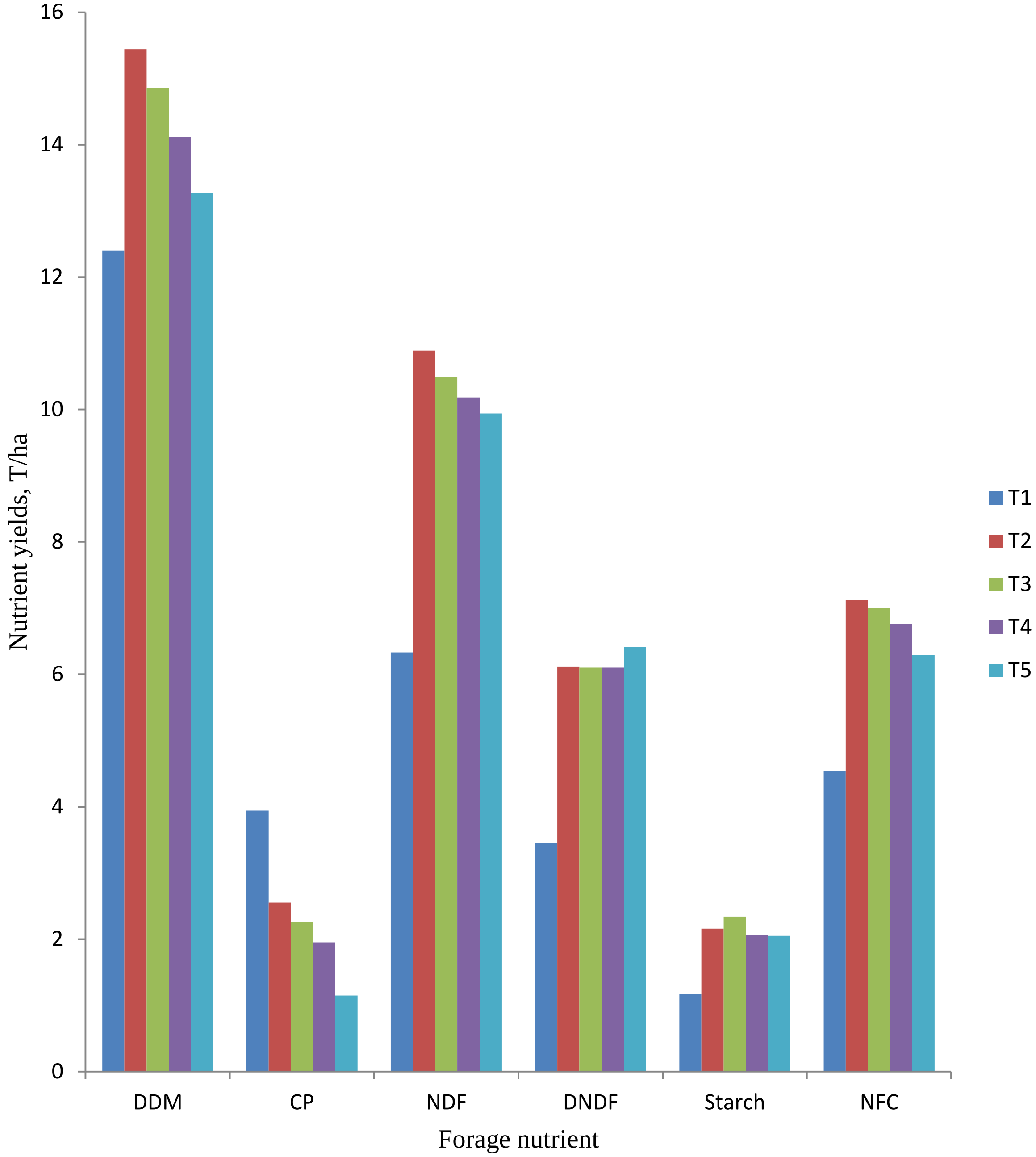

Figure 4.1. Nutrient yields of forage when Vining soybean and BMR grazing corn sown as monocropping or intercropping at different seeding ratios (T1 = 100:0 soybean and corn seeding ratio, T2 = 67:33 soybean and corn seeding ratio, T3 = 50:50 soybean and corn seeding ratio, T4 = 33:67 soybean and corn seeding ratio, T5 = 0:100 soybean and corn seeding ratio)

CHAPTER 5

LATE SEASON FORAGE YIELD, NUTRIENT YEILDS, AND QUALITY FROM ROW CROPPING OF MIXED SEEDS OF CORN AND SOYBEAN AT DIFFERENT SEEDING RATIOS

ABSTRACT

The production of forage resulting from row cropping of mixed seeds of corn and soybeans has the potential to yield greater quantities of digestible nutrients to meet the nutrient requirements of lactating dairy cows. A field plot study was laid out using a randomized complete block design to evaluate two corn hybrids [Masters Choice 5300 (Normal, NC) and BMR grazing (Masters Choice Mastergraze, MG)] with two soybeans [Large Lad RR (LL) and Big Buck 6 (BB)] at four seeding rates (R1 = 65:35; R2 = 55:45; R3 = 45:55, and R4 = 35:65 of corn and soybean) having a 2 x 2 x 4 factorial treatment design replicated three times comprised of 16 treatments. Forage was hand harvested 93 d after planting during the 2014 growing season, inoculated, packed into buckets, weighed, and ensiled for 0, 60 or 90 d. Buckets were then re-weighed, opened, and forage samples collected and submitted for nutrient analysis. Fresh biomass yield, DM yield, DDM yield, NDF yield, DNDF yield, Starch yield, NFC yield, and NE_L yield were greater for T13 ($P < 0.05$) compared to rest of the treatments. However, CP yield (T/ha) was higher ($P < 0.05$) for T7, and T15 compared to T1, T2, T3, T4, T5, T6, T8, T9, T10, T11, and T12 with T13, and T14 being intermediate. Yield of DM (6.74 and 7.65 T/ha for N and MG, respectively) for main effect of corn was similar ($P > 0.05$), while BB yielded greater ($P < 0.05$) than LL (6.13 and 8.27 T/ha for LL and BB, respectively) for main effect of soybean, while seeding ratio main effect was similar [($P > 0.05$); 7.91, 6.29, 7.81, and 6.77 T/ha for R1, R2, R3, and R4, respectively]. Yield of fresh digestible DM (DDM; 4.40 and 5.06 T/ha) and CP (1.04 and 1.22 T/ha) were similar ($P > 0.05$) for corn, while BB yielded greater ($P < 0.05$) DDM (4.03 and 5.43 T/ha) and CP (0.97 and 1.29T/ha) than LL and seeding ratios were similar ($P > 0.05$) in yield of DDM (5.20, 4.15, 5.08, and 4.50 T/ha) and CP (1.14, 1.05, 1.25, and 1.07 T/ha). A significant interaction ($P < 0.05$) was detected for corn × soybean × seeding ratio for ensiled DDM yield at 60 and 90 d, while no other significant ($P > 0.05$) interactions of main effects were detected. The combination of BMR grazing corn (MG) with BB soybean hybrids at the seeding ratio of 65:35 resulted in the greatest yield of DDM after 60 and 90 d of ensiling the forage. Continuous decreasing pH and increasing lactic acid with increased duration of ensiling suggested that forage should be ensiled for at least 90 d before feeding to the cows. The row cropping of mixed seeds of corn and soybean holds great potential for increasing the production of forages to meet the nutrient requirements of lactating dairy cows.

Key words: forage yield, row cropping, mixed seed

INTRODUCTION

Row cropping of corn and soybean mixed seed is not a well-known practice among farmers. Although intercropping and mixed cropping are considered as a modern improved approach to farming system, complication in planting and harvesting make it difficult to be adopted by farmers (Martin, 1987). Intercropping or mixed cropping of legume with non-legume usually benefits non-legume because of nitrogen fixing properties of legumes that can be utilized by non-legume (Portes, 1984; Avcioglu et al., 2003). Intercrop usually benefits from increased light interception, more soil area to root proliferation, increased microbial activity and minimizes insects, diseases and weeds to the other crop. Martin (1987) reported that rows cropping of corn and soybean mixed seed reduced the cost for nitrogen fertilizer and increased forage quality (CP% of silage) significantly although it restricts the herbicide options and complicates planting and harvesting.

Intercropping or mixed cropping of corn with soybean has a number of benefits such as low nitrogen fertilizer requirements, increased silage yield and better silage quality compared to mono-cropped corn. Numerous studies have reported that intercropping of soybean with corn elevates biomass yield by 20 to 40% (Singh et al., 1986) and CP by 11 to 15% (Putnam et al., 1986). The reason for increased silage yield with intercropping compared to monocropping is due to efficient utilization of available sunlight, moisture and soil nutrients (Etebari and Tansi, 1994). Silage quality and CP concentration increased when soybean planting with corn in alternate rows as 1corn - 1 soybean or 1 corn - 2 soybean rows compared to sole cropping of corn (Altinok et al., 2005). Smith (2000) reported increased silage yield and CP yield while intercropping corn and pole-bean together. However, intercropping of corn and soybean together generally produced less DM yield, but high quality silage (increased CP). Practicing alternate-row sowings and benefiting from climbing types of legumes as component crop had better performances than same-row sowings and dwarf type legume (Geren et al., 2008). We hypothesize that rows cropping of mixed seeds of corn and soybean at 65:35

ratios will produce greater biomass and nutrient yields compared to other seeding ratio because of better utilization of sunlight, moisture, and soil nutrients.

OBJECTIVES

The objectives of this study were to determine optimal seeding ratios under rows cropping of mixed seeds of corn and soybean to produce higher biomass yield and better nutrient yields and compare nutrients composition of silage ensiled for 0, 60 and 90 d.

MATERIALS AND METHODS

The research was conducted at the Dairy Research and Training Facility (DRTF) of South Dakota State University in late crop growing season (26th June) of the year 2014.

Field preparation

The grassland having more than 10 years of continuous grass hay production history has been converted in to research field to conduct the forage research. Soil preparation consisted of plowing, disking, leveling and layout. Field was prepared without addition of any chemical fertilizer, herbicides and pesticides. Total of 48 plots having equal areas of 36 m^2 (6 m × 6m) with 12 rows were prepared to test the treatments. Distance between two rows was 76.2 cm.

Corn and soybean varieties

Masters Choice 5300 (NC) organic forage corn (103 d maturity) is well known for strong emergence and seeding vigor for organic production and reduced tillage operation, has very good tonnage and grain yield per ha with excellent nutrition. It has wide leaf, showy robust plant, excellent dual purpose white cob variety for livestock feed that drives performance (Masters Choice Seed Corn, Anna, IL).

BMR grazing corn (Masters Choice Mastergraze, MG) is a conventional organic corn hybrid famous for best quality BMR forage. It has ability to be grazed and harvested during summer, fall and winter and potential to produce DM up to 11.21 T/ha in 7-8 weeks with ideal growing conditions. BMR grazing corn qualities include 20-30% higher digestibility, 15-20% protein potential, low lignin, sweet and palatable due to high sugar contents (Masters Choice Seed Corn, Anna, IL).

ES Large Lad RR GMO (LL) forage Soybean (90 to 110 d maturity) is known for its excellent seed yield and biomass production. It can reach heights of seven feet, stays green longer, has higher protein content than regular soybean and provide excellent forage for deer and cattle. Large Lad is easy to grow and has resistance to many foliar diseases, root rots, stem canker and races of nematodes (Eagle Seeds, Weiner, AR).

Big Buck 6 (BB), the premium non-GMO forage soybean is easy to establish, has large, high protein leaves, and has excellent forage yield among available non-GMO soybean forage varieties. It can be grown naturally without the use of herbicides. Big Buck is conventionally bred and capable of reaching heights over 1.83 m (Eagle Seeds, Weiner, AR).

Experimental design and treatments

A field plot study was laid out using a completely randomized design (CRD) to evaluate two corn hybrids [MC 5300 (NC) and Grazing BMR corn (Masters Choice Mastergraze, MG)] with two soybean hybrids [ES Large Lad RR (LL) and Big Buck 6 (BB)] at four seeding rates (R1 = 65:35; R2 = 55:45; R3 = 45:55, and R4 = 35:65 of corn and soybean) having a 2 x 2 x 4 factorial treatment design replicated three times.

The outline of total treatments was as follows:

Treatment 1 (65% MC 5300 corn + 35% Large Lad RR soybean)

Treatment 2 (55% MC 5300 corn + 45% Large Lad RR soybean)

Treatment 3 (45% MC 5300 corn + 55% Large Lad RR soybean)

Treatment 4 (35% MC 5300 corn + 65% Large Lad RR soybean)

Treatment 5 (65% MC 5300 corn + 35% Big Buck 6 soybean)

Treatment 6 (55% MC 5300 corn + 45% Big Buck 6 soybean)

Treatment 7 (45% MC 5300 corn + 55% Big Buck 6 soybean)

Treatment 8 (35% MC 5300 corn + 65% Big Buck 6 soybean)

Treatment 9 (65% Mastergraze Corn + 35% Large Lad RR soybean)

Treatment 10 (55% Mastergraze Corn + 45% Large Lad RR soybean)

Treatment 11 (45% Mastergraze Corn + 55% Large Lad RR soybean)

Treatment 12 (35% Mastergraze Corn + 65% Large Lad RR soybean)

Treatment 13 (65% Mastergraze Corn + 35% Big Buck 6 soybean)

Treatment 14 (55% Mastergraze Corn + 45% Big Buck 6 soybean)

Treatment 15 (45% Mastergraze Corn + 55% Big Buck 6 soybean)

Treatment 16 (35% Mastergraze Corn + 65% Big Buck 6 soybean)

Total seeds required for each experimental plot were calculated based on recommended seeding rate of MC 5300 corn (N) at 74,132 seeds/ha, BMR grazing corn (MG) at 86,487 seeds/ha, Large Lad RR soybean (LL) at 345,947 seeds/ha and Big Buck 6 soybean (BB) at 345,947 seeds/ha. Seeds of corn and soybean were planted by hand with distance between rows of 76.2 cm.

Weeding, harvesting, ensiling, and sampling

Weeds were removed 3 times during the cropping season at 25 and 50 d by using small rotary tiller and manually at 75 d after planting. No irrigation was provided throughout the study period. Forages from two central rows of each experimental plot were hand harvested at 93 d after planting and fresh biomass yield was recorded. Plants were chopped with locally made shredder/chipper, treated with *lactobacillus* inoculant (Silo-King® Plus, Agriking Inc., Fulton, IL) at recommended dose, packed into buckets, weighed, and ensiled for 0, 60, or 90 d. Buckets were then re-weighed, opened, and forage samples collected and submitted for nutrient analysis (Analab, Inc., Fulton, IL).

Sample analyses

Fresh (0), 60 and 90 d ensiled forage samples were analyzed for DM, CP,SP, ADF, NDF,ADIP, NDIP, Starch, NFC, NE_L, 6-C sugar, EE, nitrates, IVDMD, NDFD30, lignin, ash, NH_3-N, pH, lactic acid, acetic acid, butyric acid, Na, Mg, P, S, K, Ca, Cl, Mn, Fe, Cu and Zn (Analab, Inc., Fulton, IL). The AOAC (2006) was used to analyze DM (935.29), CP (990.03), SP (Krishnamoorthy et al., 1982), ADF (973.18), NDF (2002.04), ADIP (Goering and Van Soest, 1970; Goering et al., 1972), NDIP (2002.04 minus sulfite and 976.06), Starch (996.11, enzymatic method analyzed on RFA using glucose trinder), NFC (100- NDF – CP – Fat – EE), NE_L (NRC,2001), 6-C Sugar (Ethanol extract, HPLC with ELSD), EE (920.39), nitrates (968.07), IVDMD (ANKOM technology - 08/05), NDFD (ANKOM technology method 3), lignin (973.18), Ash (942.05), NH_3-N (University of Wisconsin Extension SKU:A3769, MAP 4.3 adapted from USEPA 351.2 and ISO 11732), pH (981.12), lactic acid (LC-GC Vol. 11 No. 10), acetic Acid (LC-GC Vol. 11 No. 10), butyric acid (LC-GC Vol. 11 No. 10) and minerals (Ca, P, Mg, K, Na: 985.01; S: 923.01; Cl: 915.01; Mn, Fe, Cu, ZN:985.01).

Estimation of total nitrogen accumulated by the crop

Total nitrogen accumulated by the crops (T/ha) can be calculated as follows:

$$\text{Total N} = \Sigma\,(\text{DMY} \times \text{N}\,\%)$$

Where DMY is the yield of DM (T/ha) and N is the concentration of nitrogen in plant. Crude protein content of forage was used to calculate total nitrogen content. Once DMY per ha was multiplied by nitrogen percentage, we can get total nitrogen uptake by treatment forage on per ha basis.

Statistical analysis

Statistical analysis of all data were performed by using the PROC MIXED procedure of SAS subjected to least squares ANOVA (SAS Institute Inc., Cary, NC, Version 9.4) for a completely randomized design (Steel and Torrie, 1980). Data were tested for heterogeneity of variances and statistical significance was declared at $P \leq 0.05$.

Statistical model used for this experiment was as follows:

$$Y_{ijk} = \mu + C_i + S_j + R_k + (C \times S)_{ij} + (C \times R)_{ik} + (S \times R)_{jk} + (C \times S \times R)_{ijk} + e_{ijk}$$

Where,

Y_{ijk} is the dependent variable

μ is the overall mean,

C_i is the i^{th} main effect of corn ($i = 1,2$)

S_j is the j^{th} main effect of corn ($j = 1,2$)

R_k is the k^{th} main effect of seeding ratio ($k = 1,2,3,4$)

$(C \times S)_{ij}$ is the interaction of corn and soybean

$(C \times R)_{ik}$ is the interaction of corn and seeding ratio

$(S \times R)_{jk}$ is the interaction of soybean and seeding ratio

$(C \times S \times R)_{ijk}$ is the interaction of corn, soybean and seeding ratio (treatment)

e_{ijk} = error term

RESULTS AND DISCUSSION

Temperature and rainfall patterns of crop growing season

The growing crop season of 2014 was normal in terms of temperature but received very high rainfall (Table 5.1) when compared to the average temperature and precipitation for the past 30 years. High soil moisture may affect germination of seeds, growth and nutrient content of whole plant. We observed low germination of corn due to heavy rainfall just after planting.

Forage and nutrient yields of different experimental treatments

Forage and nutrient yields from different experimental treatments are presented in Table 5.2. Fresh biomass yield, DM yield, DDM yield, NDF yield, DNDF yield, Starch yield, NFC yield, and NE_L yield were greater for T13 ($P < 0.05$) compared to rest of the treatments (18.52, 8.66, 16.06, 17.69, 17.79, 20.29, 20.35, 13.76,17.76, 13.17, 14.62, 11.83, 27.72, 18.09, 21.46 and 21.16 T/ha fresh biomass yield; 6.55, 3.49, 5.59, 7.83, 6.79, 7.53, 10.02, 6.12, 7.93, 5.85, 6.67, 5.10, 10.38, 8.31, 8.96, and 8.04 T/ha DM yield; 4.33, 2.33, 3.61, 5.14, 4.53, 5.03, 6.55, 4.02, 5.34, 3.90, 4.42, 3.41, 6.95, 5.54, 5.92,and

5.40 T/ha DDM yield; 3.12, 1.56, 2.64, 3.55, 3.12, 3.52, 4.56, 2.84, 3.82, 2.72, 3.19, 2.33, 4.95, 3.79, 4.22, and 3.81 T/ha NDF yield; 1.55, 0.77, 1.22, 1.68, 1.54, 1.78, 2.21, 1.37, 2.06, 1.38, 1.63, 1.18, 2.59, 1.92, 2.08, and 1.96 T/ha NDFD yield; 0.84, 0.41, 0.54, 0.87, 0.82, 0.87, 1.16, 0.68, 0.86, 0.54, 0.60, 0.49, 1.30, 0.71, 0.72, and 0.77 T/ha starch yield; 2.09, 1.14, 1.69, 2.47, 2.18, 2.37, 3.20, 1.91, 2.40, 1.73, 1.96, 1.58, 3.37, 2.55, 2.61, and 2.47 T/ha NFC; 9740, 5267, 8080, 11621, 10218, 11146, 14703, 8995, 11593, 8520, 9632, 7788, 15231, 12165, 12926, and 11613 Mcal/ ha NE_L yield for T1, T2, T3,T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, and T16 respectively). DM loss (T/ha) when ensiled was lower ($P < 0.05$) for T10, and T14 compared to T2 and T15 with other treatments being intermediate and similar. The CP yield was higher ($P < 0.05$) for T7, and T15 compared to T1, T2, T3,T4, T5, T6, T8, T9, T10, T11, and T12 with T13, and T14 being intermediate. Milk yield estimated through Milk2006 (Shaver et al., 2006) was greater ($P < 0.05$) for T13 compared to rest of the treatments with T7 being similar (7.63, 3.91, 5.70, 8.52, 7.87, 8.48, 10.90, 6.73, 9.20, 6.56, 7.29, 5.49, 12.00, 8.59, 9.31, and 8.81 T/ha milk for T1, T2, T3,T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, and T16 respectively). Total N accumulation by treatment forage was greater ($P < 0.05$) for T7, T13, T14, T15, and T16 compared to T1, T2, and T12 with other being intermediate and similar (0.14, 0.10, 0.14, 0.20, 0.18, 0.19, 0.25, 0.15, 0.20, 0.17, 0.16, 0.13, 0.22, 0.21, 0.25, and 0.21 T/ha N for T1, T2, T3,T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, and T16 respectively). Thus, seeding ratio of MG corn and BB soybean at 65:35 (T13) produced more DDM and nutrient yields compared to NC corn and LL soybean combination and other seeding ratios. Thus, MG corn and BB soybean are the recommended corn and soybean varieties when planting at late season. Soybean has been successfully intercropped with different cereals including corn, oat, barley, sorghum and wheat (Anil et al., 1998) and other crops like cassava and cow pea (Quainoo et al., 2000; Li et al., 2001; Chabi- Olaye et al., 2005). Forage production from corn and soybean intercropping was comparable with that from corn monocropping (Sheaffer et al., 2001). When corn growth is limited and poorly established, soybean is able to establish well and produce yields equivalent to those of monocrop soybean (Carruthers et al., 2000).

Forage nutrient composition of different experimental treatments

Nutrient composition of forage produced from the different treatments is listed in Table 5.3. Crude protein concentration of forage was greater in T10 ($P < 0.05$) compared to T1, T2, T3, T5, T6, T7, T8, T9, T13, and T16 with T4, T11, T12, T14, and T15 being intermediate. Soluble protein concentration of forage was greater ($P < 0.05$) for T1, T5, and T16 compared to T3, T7, and T8 with rest of the treatments being intermediate. The NDF concentration was greater ($P < 0.05$) for T9 compared to T2, T4, T5, T7, T12 and T14 with rest of the treatments being intermediate. Starch concentration of forage was greater ($P < 0.05$) for T1, and T13 compared to T3, T4, T10, T11, T12, T14, T15, and T16 with other treatments being intermediate. The NFC concentration of forage was greater ($P < 0.05$) for T13 compared to T9, T10, T11, and T15 with other treatments being intermediate. Sugar concentration of forage was greater ($P < 0.05$) for T9 compared to rest of the treatments with T6, and T13 being intermediate. Thirty hours NDFD of forage was greater ($P < 0.05$) for T9, T12, and T14 compared to rest of the treatments with T13 being intermediate. Lignin concentration was greater ($P < 0.05$) for T10 compared to T1, T5, T6, T7, T9, and T13 with other treatments being intermediate.

Lactic acid concentration was greater ($P < 0.05$) for T11 compared to T1, T2, T3, T4, T5, T7, T8, T9, T12, T15, and T16 with other treatments being intermediate.

Forage and nutrient yields when ensiled for 0, 60, or 90 d

Forage and nutrient yields of forage ensiled for different periods is presented in Table 5.4. DM yield, DDM yield, and CP yield of forage was similar ($P > 0.05$) across different ensiling periods (7.20 T/ha, 4.78 T/ha, and 1.11 T/ha for DM yield, DDM yield, and CP yield respectively). DM loss (T/ha) was lower ($P < 0.05$) when ensiled for 90 d (2.04) compared to 60 d (2.66). Yield of forage NDF was lower ($P < 0.05$) when ensiled for 90 d compared to 0 or 60 d (3.48, 3.49, and 3.19 T/ha for 0, 60, and 90 d respectively). Yield of forage DNDF was lower ($P < 0.05$) when ensiled for 90 d compared to 60 d with 0 d being intermediate (1.69, 1.78, and 1.59 T/ha for 0, 60, and 90 d respectively). Starch yield was higher ($P < 0.05$) for forage ensiled for 90 d compared to 0 or 60 d (0.72, 0.72, and 0.82 T/ha for 0, 60, and 90 d respectively). The NFC yield was greater ($P < 0.05$) when ensiled for 90 d compared to 0 or 60 d (2.14, 2.09, 2.44 T/ha for 0, 60, and 90 d respectively). The NE_L yield was similar ($P > 0.05$) across the ensiling periods (10559 Mcal/ha). Similarly, estimated milk yield was similar ($P > 0.05$) across the ensiling periods (7.94 T/ha).

Nutrient composition of forage when ensiled for 0, 60, or 90 d

Nutrient contents of silage ensiled for 0, 60, and 90 d are presented in Table 5.5. There is a decreasing trend of CP ($P < 0.10$) when duration of ensiling increased from 0 to 90 d (15.98, 15.93, and 15.19% CP for 0, 60, and 90 d respectively). The SP concentration of forage elevated ($P < 0.05$) with increased ensiling period (35.56, 36.29, and 42.66% for 0, 60, and 90 d ensiled respectively). The NDF and ADF concentration of forage were lower ($P < 0.05$) when ensiling for 90 d compared to 0 and 60 d (47.84, 48.43, and 44.02% NDF; 30.24, 31.36, and 28.68% ADF for 0, 60, and 90 d respectively). Starch and NFC concentrations of forage were greater ($P < 0.05$) when ensiling for 90 d compared to 0 and 60 d (9.45, 9.55, and 11.66% Starch; 29.50, 28.69, and 34.29% NFC for 0, 60, and 90 d respectively). Fiber digestibility for 30 h (NDFD30) was lower ($P < 0.05$) in 0 d ensiling forage compared to 60, and 90 d (47.84, 50.96, and 49.38% for 0, 60, and 90 d respectively). The pH of the forage ensiling for 90 d was lower ($P < 0.05$) than 0 d and 60 d being intermediate (4.83, 4.51, and 4.27 for 0, 60, and 90 d respectively). Lactic acid concentration of forage was elevated ($P < 0.05$) with increased duration of ensiling (3.92, 5.00, and 6.38% for 0, 60, and 90 d respectively). Continuous decreasing pH and increasing lactic acid with increased ensiling duration suggested that forage should be ensiled at least for 90 d or more before feeding to the cows. Newbold et al. (2006) reported that 3 h in situ starch degradability increased with ensiling time was correlated with corn silage DM content at time of ensiling. Mean 3 h in situ starch digestibility was 53.2% at 60 d and 69% at 300 d after ensiling. The CP degradation increased with storage time, but was not correlated with starch digestibility. Time after ensiling of corn silage may be an important to consider for diet formulation because of changes in digestibility of different nutrients. Diet adaptations, such as adjusting starch level in the TMR could be done when starch digestibility improves in order to prevent acidosis. Both ensiling temperature and ensiling duration play an important role in the rumen degradation of corn silage (Ali et al., 2015). Ward and de

Ondarza (2008) reported that lactic acid, pH, titrable acidity, and soluble protein didn’t reach maximum levels until 4 months after ensiling. Thus, at least 4 months are essential for full fermentation of corn silage.

Main effects of corn and soybean on nutrient composition of forage

Main effect of corn and soybean on nutrient composition of forage when row cropping of mixed seed of corn and soybean with different seeding ratios are listed in Table 5.6. The main effect of corn for CP concentration was greater (P <0.05) for MG compared to N (15.31 and 16.09% CP for NC and MG respectively). However, the main effect of soybean for CP concentration was similar (P <0.05) for LL and BB (15.99% CP). The main effect of corn for SP concentration was similar for NC and MG (38.18% SP) but soybean for SP concentration was greater for BB compared to LL (37.81, and 38.54% SP for LL and BB respectively). The main effect of corn for starch and NFC concentration were greater (P <0.05) for N compared to MG (11.17, and 9.27% starch and 31.51, and 30.14% NFC for NC and MG respectively) but main effect of soybean for starch and NFC concentration were similar (P > 0.05) for LL and BB (10.22% starch and 30.83% NFC). The main effect of corn on fiber digestibility for 30 h (NDFD30) and lactic acid concentration was greater (P < 0.05) for MG compared to NC (48.22, and 50.57% NDFD and 4.84, and 5.36% lactic acid for NC and MG respectively).

CONCLUSIONS

The row cropping of mixed seeds of corn and soybean holds a great promise for the production of high quality forages for dairy cattle. The seeding ratios, as well as, types of corn and soybean affects the total forage yield and nutrient yields. The greatest yield of nutrients occurred with BMR grazing corn in combination with Big buck 6 soybean at a seeding ratio of 65:35. Forage studies evaluating silage quality should be for a minimum of 90 d to ensure that ensiling process is completed because the lactic acid concentrations were greatest at 90 d. Row cropping of mixed seeds of corn and soybean can increase the CP concentrations of corn silage. BMR grazing corn is higher in crude protein, but lower in starch than MC 5300 corn. Big Buck 6 is high quality soybean forage that is comparable in nutrient composition to ES Large Lad RR soybean. Mixed cropping of a Big Buck 6 forage soybean in conjunction with either corn grown for silage offers the potential for the production of high biomass with a highly digestible nutrient composition.

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Table 5.1. Climatic conditions during the 2014 growing season[1]

	Temperature, °C		Precipitation, mm	
Months	Mean	Deviation[2]	Total	Deviation[2]
April	5.0	-1.5	44.5	-14.1
May	12.8	-0.7	814.3	730.5
June	18.9	0.0	224.0	113.2
July	19.4	-1.9	61.2	-18.9
August	20.0	0.0	73.7	-0.5
September	15.6	0.5	50.8	-28.2
October	8.9	1.4	16.8	-33.3
November	-5.0	-4.2	19.6	1.9

[1] Data collected from a weather station located at South Dakota State University approximately 3 km from the plots.

[2] Deviation = actual minus 30 year monthly average.

Table 5.2. Forage and nutrient yields (T/ha unless noted) when row cropping of mixed seed of corn and soybean with different seeding ratios

Yield	Treatments[1]																SEM
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	
Fresh	18.52^{cd}	8.66^{h}	16.06^{de}	17.69^{d}	17.79^{d}	20.29^{bc}	20.35^{bc}	13.76^{efg}	17.76^{d}	13.17^{fg}	14.62^{ef}	11.83^{g}	27.72^{a}	18.09^{cd}	21.46^{b}	21.16^{b}	0.87
DM[2]	6.55^{fgh}	3.49^{j}	5.59^{hi}	7.83^{cdef}	6.79^{efgh}	7.53^{defg}	10.02^{ab}	6.12^{ghi}	7.93^{cdef}	5.85^{hi}	6.67^{fgh}	5.10^{i}	10.38^{a}	8.31^{cd}	8.96^{bc}	8.04^{cde}	0.47
DM loss	1.99^{bc}	3.09^{a}	2.12^{bc}	1.98^{bc}	1.95^{bc}	1.92^{bc}	2.34^{abc}	2.44^{abc}	1.93^{bc}	1.54^{c}	1.92^{bc}	1.80^{bc}	2.01^{bc}	1.71^{c}	2.66^{ab}	2.31^{abc}	0.34
DDM[3]	4.33^{fgh}	2.33^{i}	3.61^{gh}	5.14^{cdef}	4.53^{defg}	5.03^{cdef}	6.55^{ab}	4.02^{gh}	5.34^{cde}	3.90^{gh}	4.42^{efg}	3.41^{h}	6.95^{a}	5.54^{c}	5.92^{bc}	5.40^{cd}	0.32
CP[4]	0.92^{fgh}	0.55^{i}	0.85^{gh}	1.24^{bc}	1.06^{cdefg}	1.13^{cdef}	1.52^{a}	0.95^{efgh}	1.17^{bcde}	1.00^{defgh}	1.08^{cdef}	0.83^{h}	1.35^{ab}	1.38^{ab}	1.51^{a}	1.21^{bcd}	0.08
NDF[5]	3.12^{efg}	1.56^{i}	2.64^{gh}	3.55^{cde}	3.12^{efg}	3.52^{def}	4.56^{ab}	2.84^{fgh}	3.82^{cd}	2.72^{gh}	3.19^{defg}	2.33^{h}	4.95^{a}	3.79^{cde}	4.22^{bc}	3.81^{cd}	0.40
DNDF[6]	1.55^{efg}	0.77^{h}	1.22^{g}	1.68^{def}	1.54^{efg}	1.78^{cde}	2.21^{b}	1.37^{fg}	2.06^{bc}	1.38^{fg}	1.63^{def}	1.18^{g}	2.59^{a}	1.92^{bcde}	2.08^{bc}	1.96^{cd}	0.16
Starch	0.84^{b}	0.41^{g}	0.54^{def}	0.87^{b}	0.82^{bc}	0.87^{b}	1.16^{a}	0.68^{cde}	0.86^{b}	0.54^{def}	0.60^{cdef}	0.49^{ef}	1.30^{a}	0.71^{bcde}	0.72^{bcde}	0.77^{bcd}	0.09
NFC[7]	2.09^{cdefg}	1.14^{i}	1.69^{gh}	2.47^{bc}	2.18^{bcdef}	2.37^{bcde}	3.20^{a}	1.91^{efgh}	2.40^{bcd}	1.73^{fgh}	1.96^{defgh}	1.58^{hi}	3.37^{a}	2.55^{bc}	2.61^{b}	2.47^{bc}	0.16
$NE_{L,}$ Mcal/ha	9740^{efg}	5267^{i}	8080^{gh}	11621^{cde}	10218^{def}	11146^{cde}	14703^{ab}	8995^{fgh}	11593^{cde}	8520^{fgh}	9632^{efg}	7488^{h}	15231^{a}	12165^{cd}	12926^{bc}	11613^{cde}	689
Milk[8]	7.63^{cd}	3.91^{e}	5.70^{de}	8.52^{bcd}	7.87^{cd}	8.48^{bcd}	10.90^{ab}	6.73^{cd}	9.20^{bc}	6.56^{d}	7.29^{cd}	5.49^{de}	12.00^{a}	8.59^{bc}	9.31^{bc}	8.81^{bc}	0.95
N[9]	0.14^{b}	0.10^{b}	0.14^{ab}	0.20^{ab}	0.18^{ab}	0.19^{ab}	0.25^{a}	0.15^{ab}	0.20^{ab}	0.17^{ab}	0.16^{ab}	0.13^{b}	0.22^{a}	0.21^{a}	0.25^{a}	0.21^{a}	0.04

[a,b,c,d,e,f,g,h,i,j] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 65% MC 5300 corn + 35% Large Lad RR soybean, T2 = 55% MC 5300 corn + 45% Large Lad RR soybean, T3 = 45% MC 5300 corn + 55% Large Lad RR soybean, T4 = 35% MC 5300 corn + 65% Large Lad RR soybean, T5 = 65% MC 5300 corn + 35% Big Buck 6 soybean, T6 = 55% MC 5300 corn + 45% Big Buck 6 soybean, T7 = 45% MC 5300 corn + 55% Big Buck 6 soybean, T8 = 35% MC 5300 corn + 65% Big Buck 6 soybean, T9 = 65% Mastergraze Corn + 35% Large Lad RR soybean, T10 = 55% Mastergraze Corn + 45% Large Lad RR soybean, T11 = 45% Mastergraze Corn + 55% Large Lad RR soybean, T12 = 35% Mastergraze Corn + 65% Large Lad RR soybean, T13 = 65% Mastergraze Corn + 35% Big Buck 6 soybean, T14 = 55% Mastergraze Corn + 45% Big Buck 6 soybean, T15 = 45% Mastergraze Corn + 55% Big Buck 6 soybean, T16 = 35% Mastergraze Corn + 65% Big Buck 6 soybean

[2] Dry matter; [3] Digestible dry matter; [4] Crdue protein; [5] Neutral detergent fiber; [6] Digestible neutral detergent fiber; [7] Non fiber carbohydrate, [8] Milk yield potential of forage estimated through MILK2006; [9] Nitrogen accumulation by treatment forage

Table 5.3. Nutrient composition of forage when row cropping of mixed seed of corn and soybean with different seeding ratios

Nutrients	Treatments[1]																
composition	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	SEM
DM	38.23^{bcd}	39.39^{abc}	40.76^{ab}	40.94^{ab}	39.93^{abc}	39.69^{abc}	39.88^{abc}	40.08^{abc}	35.02^{d}	40.22^{abc}	36.80^{abc}	41.35^{ab}	36.82^{cd}	38.03^{bcd}	39.43^{abc}	42.11^{a}	2.04
	……% of DM unless noted……																
CP	13.89^{gf}	15.81^{bcde}	14.92^{def}	16.08^{abcde}	5.45^{bcdef}	15.33^{bcdef}	14.99^{cdef}	15.37^{bcdef}	14.67^{efg}	17.79^{a}	16.54^{abcd}	16.77^{abc}	12.97^{g}	16.94^{ab}	16.74^{abc}	15.66^{bcdef}	0.78
SP^{2}, % of CP	40.59^{a}	38.57^{abc}	36.75^{c}	38.25^{abc}	40.47^{a}	40.30^{ab}	37.48^{bc}	37.22^{c}	38.93^{abc}	39.03^{abc}	38.55^{abc}	37.75^{abc}	39.50^{abc}	39.38^{abc}	39.42^{abc}	40.50^{a}	0.92
ADF	29.27^{cd}	29.24^{cd}	30.91^{ab}	29.91^{abcd}	28.46^{d}	29.40^{bcd}	29.82^{abcd}	30.16^{abc}	30.35^{abc}	30.57^{abc}	30.93^{ab}	29.77^{abcd}	29.79^{abcd}	30.00^{abcd}	31.13^{a}	31.15^{a}	0.74
NDF	47.40^{abc}	45.14^{c}	47.18^{abc}	45.51^{bc}	45.60^{bc}	46.32^{abc}	45.60^{bc}	46.65^{abc}	48.29^{a}	46.02^{abc}	47.49^{ab}	45.30^{bc}	47.35^{abc}	45.21^{bc}	47.16^{abc}	47.14^{abc}	0.85
$ADIP^{3}$	0.65^{e}	0.80^{abc}	0.79^{abcd}	0.75^{bcde}	0.68^{de}	0.68^{de}	0.77^{abcd}	0.78^{abcd}	0.70^{cde}	0.88^{a}	0.80^{abc}	0.82^{abc}	0.65^{e}	0.80^{abc}	0.84^{ab}	0.77^{abcd}	0.07
$NDIP^{4}$	2.05^{ed}	2.50^{bc}	2.43^{bc}	2.53^{bc}	2.34^{cde}	2.33^{cde}	2.43^{bc}	2.51^{bc}	2.40^{bcd}	2.93^{a}	2.74^{ab}	2.72^{ab}	1.99^{e}	2.67^{abc}	2.67^{abc}	2.47^{bc}	0.15
Starch	13.22^{a}	11.06^{abcd}	9.82^{cde}	10.35^{bcde}	12.92^{ab}	11.03^{abcd}	11.76^{abc}	10.97^{abcd}	10.83^{abcd}	8.53^{de}	8.58^{de}	9.54^{cde}	13.22^{a}	8.42^{de}	8.01^{e}	8.82^{ed}	1.37
NFC^{5}	32.51^{ab}	32.40^{ab}	30.72^{abc}	31.22^{abc}	32.84^{ab}	31.80^{abc}	32.33^{ab}	31.28^{abc}	30.30^{bc}	29.38^{c}	29.37^{c}	31.29^{abc}	33.09^{a}	30.92^{abc}	29.28^{c}	30.53^{abc}	1.18
NE_{L}, Mcal/kg	1.49^{ab}	1.49^{ab}	1.45^{cd}	1.48^{abcd}	1.51^{a}	1.49^{abc}	1.48^{abcd}	1.47^{bcd}	1.46^{bcd}	1.46^{bcd}	1.45^{cd}	1.48^{abcd}	1.47^{abcd}	1.47^{abcd}	1.44^{d}	1.44^{d}	0.02
Sugar	0.31^{bc}	0.38^{bc}	0.21^{c}	0.22^{c}	0.27^{c}	0.50^{ab}	0.31^{bc}	0.40^{bc}	0.68^{a}	0.32^{bc}	0.25^{c}	0.29^{c}	0.50^{ab}	0.26^{c}	0.36^{bc}	0.32^{bc}	0.10
EE	1.85^{bcd}	1.83^{cde}	1.80^{de}	1.87^{bcd}	1.97^{a}	1.87^{abcd}	1.92^{abc}	1.93^{abc}	1.81^{de}	1.95^{ab}	1.84^{bcde}	1.89^{abcd}	1.84^{cde}	1.82^{cde}	1.85^{bcd}	1.74^{e}	0.05
$IVDMD^{6}$	66.40^{abc}	66.43^{abc}	64.77^{d}	65.67^{bcd}	67.16^{a}	67.16^{a}	65.62^{cd}	66.10^{abcd}	67.57^{a}	66.94^{abc}	66.74^{abc}	67.15^{a}	67.02^{abc}	67.12^{a}	66.14^{abcd}	67.01^{abc}	0.96
$NDFD^{7}$	50.01^{bcd}	48.37^{cde}	46.36^{e}	47.15^{de}	49.63^{bcd}	50.50^{bc}	48.37^{cde}	48.88^{bcde}	53.86^{a}	50.71^{bc}	51.39^{a}	50.01^{bcd}	51.70^{ab}	50.62^{bc}	49.56^{bcd}	50.27^{bc}	1.50
Lignin	3.27^{def}	3.90^{abc}	3.96^{abc}	3.99^{ab}	3.53^{bcde}	3.44^{cdef}	3.66^{bcde}	3.79^{abcd}	3.24^{ef}	4.26^{a}	3.80^{abcd}	3.94^{abc}	2.99^{f}	3.79^{abcd}	3.90^{abc}	3.73^{abcde}	0.27
Ash	6.39^{d}	7.30^{abc}	7.80^{a}	7.84^{a}	6.47^{d}	7.01^{bcd}	7.64^{ab}	7.27^{abc}	7.31^{abc}	7.79^{a}	7.48^{ab}	7.46^{ab}	6.74^{cd}	7.77^{a}	7.64^{ab}	7.38^{abc}	0.31
pH, scale	4.28^{def}	4.68^{ab}	4.61^{abcd}	4.50^{abcdef}	4.42^{bcdef}	1.22^{ef}	4.32^{bcdef}	4.45^{bcdef}	4.30^{cdef}	4.52^{abcdef}	4.30^{cdef}	4.57^{abcde}	4.18^{f}	4.44^{bcdef}	4.83^{a}	4.66^{abc}	0.21

Lactic acid	5.15^{cd}	4.94^{d}	5.01^{d}	5.47^{bcd}	5.07^{d}	5.66^{abcd}	5.15^{cd}	5.01^{d}	5.41^{bcd}	6.03^{abc}	6.45^{a}	5.39^{bcd}	5.63^{abcd}	6.16^{ab}	5.27^{bcd}	5.25^{cd}	0.34
Acetic acid	1.47^{ab}	1.41^{ab}	1.04^{bc}	0.86^{c}	1.04^{bc}	1.17^{abc}	1.14^{abc}	1.09^{abc}	0.87^{c}	1.16^{abc}	1.39^{ab}	0.92^{c}	1.30^{abc}	1.21^{abc}	1.54^{a}	1.37^{ab}	0.25

[a,b,c,d,e,f,g,h] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 65% MC 5300 corn + 35% Large Lad RR soybean, T2 = 55% MC 5300 corn + 45% Large Lad RR soybean, T3 = 45% MC 5300 corn + 55% Large Lad RR soybean, T4 = 35% MC 5300 corn + 65% Large Lad RR soybean, T5 = 65% MC 5300 corn + 35% Big Buck 6 soybean, T6 = 55% MC 5300 corn + 45% Big Buck 6 soybean, T7 = 45% MC 5300 corn + 55% Big Buck 6 soybean, T8 = 35% MC 5300 corn + 65% Big Buck 6 soybean, T9 = 65% Mastergraze Corn + 35% Large Lad RR soybean, T10 = 55% Mastergraze Corn + 45% Large Lad RR soybean, T11 = 45% Mastergraze Corn + 55% Large Lad RR soybean, T12 = 35% Mastergraze Corn + 65% Large Lad RR soybean, T13 = 65% Mastergraze Corn + 35% Big Buck 6 soybean, T14 = 55% Mastergraze Corn + 45% Big Buck 6 soybean, T15 = 45% Mastergraze Corn + 55% Big Buck 6 soybean, T16 = 35% Mastergraze Corn + 65% Big Buck 6 soybean

[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro neutral detergent fiber digestibility for 30 h

Table 5.4. Nutrient yields (T/ha unless indicated) of forage when row cropping of mixed seeds of corn and soybean with different seeding ratios ensiled for 0, 60 or 90 days

	Days of ensiled[1]			
Nutrient yields	0	60	90	SEM
DM[2]	7.20	7.20	7.20	0.19
DM loss	-	2.48[a]	2.03[b]	0.11
DDM[3]	4.73	4.80	4.81	0.23
CP[4]	1.13	1.12	1.08	0.05
NDF[5]	3.48[a]	3.49[a]	3.19[b]	0.17
DNDF[6]	1.69[ab]	1.78[a]	1.59[b]	0.09
Starch	0.72[b]	0.72[b]	0.82[a]	0.04
NFC[7]	2.14[b]	2.09[b]	2.44[a]	0.06
NE_L[8], Mcal/ha	10534	10314	10828	513.60
Milk[9]	7.88	8.18	7.75	0.41

[a,b] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] 0 = fresh or ensiled for 0 days, 60 = ensiled for 60 days, 90 = ensiled for 90 days

[2] Dry matter; [3] Digestible dry matter; [4] Crdue protein; [5] Neutral detergent fiber; [6] Digestible neutral detergent fiber; [7] Non fiber carbohydrate; [8] Estimated net energy for lactation through NRC (2001); [9] Milk yield potential of forage estimated through MILK2006

Table 5.5. Nutrient composition of forage when row cropping of mixed seeds of corn and soybean with different seeding ratios ensiled for 0, 60, or 90 days

	Days of ensiled[1]			
Nutrients composition	0	60	90	SEM
DM, %	40.94^{a}	38.57^{b}	39.46^{a}	0.54
-----------------------------------% of DM unless noted------------------------------------				
CP	15.98^{e}	15.93^{e}	15.19^{f}	0.29
SP[2], % of CP	35.56^{b}	36.29^{b}	42.66^{a}	0.36
ADF	30.24^{b}	31.36^{a}	28.68^{c}	0.23
NDF	47.84^{a}	48.43^{a}	44.02^{b}	0.32
ADIP[3]	0.74^{b}	0.81^{a}	0.71^{b}	0.02
NDIP[4]	2.69^{a}	2.74^{a}	2.16^{b}	0.06
Starch	9.45^{b}	9.55^{b}	11.66^{a}	0.39
NFC[5]	29.50^{b}	28.69^{b}	34.29^{a}	0.35
NE_L, Mcal/kg	1.46^{b}	1.43^{c}	1.50^{a}	0.01
Sugar	0.24^{b}	0.37^{a}	0.36^{a}	0.02
EE	1.74^{c}	1.93^{a}	1.83^{b}	0.02
IVDMD[6]	65.58^{b}	66.68^{a}	66.77^{a}	0.22
NDFD[7]	47.84^{c}	50.96^{a}	49.38^{b}	0.43
Lignin	3.63^{b}	3.95^{a}	3.46^{b}	0.08
Ash	7.21^{b}	7.71^{a}	6.99^{b}	0.11
pH, scale	4.83^{a}	4.51^{b}	4.27^{c}	0.05
Lactic acid	3.92^{c}	5.00^{b}	6.38^{a}	0.11
Acetic acid	1.29^{a}	1.38^{a}	0.96^{b}	0.07
Lactic: Acetic, Ratio	7.74^{b}	7.72^{b}	10.75^{a}	1.64

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] 0 = fresh or ensiled for 0 days, 60 = ensiled for 60 days, 90 = ensiled for 90 days

[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro neutral detergent fiber digestibility for 30 h

Table 5.6. Main effect of corn and soybean on nutrient composition of forage when row cropping of mixed seeds of corn and soybean with different seed ratios

Nutrient composition	Main effects[1]				SEM
	Corn		Soybean		
	NC	MG	LL	BB	
DM%	40.23^e	39.09^f	39.46	39.86	0.47
------------------------------------% of DM unless note------------------------------------					
CP	15.31^b	16.09^a	15.89	15.51	0.24
SP[2], % of CP	37.96	38.39	37.81^b	38.54^a	0.29
ADF	29.69^b	30.50^a	30.16	30.03	0.19
NDF	46.47	47.05	46.85	46.68	0.26
ADIP[3]	0.73^b	0.78^a	0.77	0.74	0.01
NDIP[4]	2.44^b	2.62^a	2.58^f	2.47^e	0.05
Starch	11.17^a	9.27^b	10.02	10.42	0.35
NFC[5]	31.51^a	30.14^b	30.52	31.13	0.30
NE_L, Mcal/kg	1.48^a	1.46^b	1.47	1.47	0.04
Sugar	0.30	0.35	0.31	0.34	0.02
EE	1.85^a	1.81^b	1.83	1.84	0.01
IVDMD[6]	65.95^b	66.74^a	66.45	66.45	0.20
NDFD[7]	48.22^b	50.57^a	49.29	49.50	0.39
Lignin	3.68	3.69	3.78^a	3.59^b	0.07
Ash	7.19^f	7.42^e	7.40	7.21	0.09
pH, Scale	4.52	4.56	4.55	4.52	0.05
Lactic acid	4.84^b	5.36^a	5.14	5.06	0.10
Acetic acid	1.18	1.24	1.16	1.26	0.06
Lactic: Acetic, Ratio	9.66	7.81	7.56	9.91	1.99

^{a,b}Least squares means within the same row without a common superscript differ ($P < 0.05$)
^{e,f}Least squares means within the same row without a common superscript differ ($P < 0.10$)
[1] NC = MC 5300 corn, MG = mastergraze corn, LL = large lad RR soybean, BB = big buck 6 soybean
[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro neutral detergent fiber digestibility for 30 h

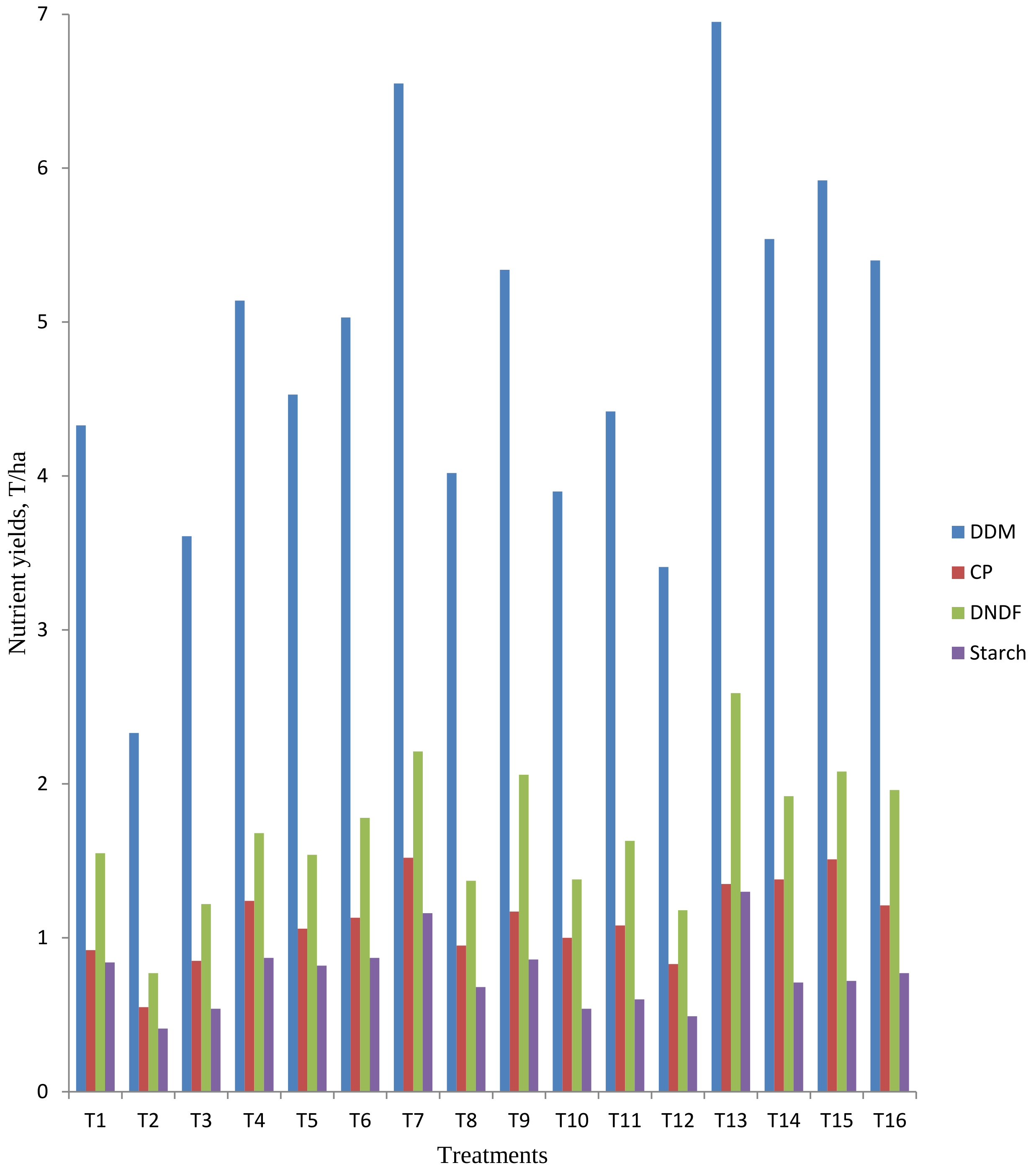

Figure 5.1 Nutrient yields of forage when row cropping of mixed seeds of corn and soybean with different seeding ratios (T1 = 65% MC 5300 corn + 35% Large Lad RR soybean, T2 = 55% MC 5300 corn + 45% Large Lad RR soybean, T3 = 45% MC 5300

corn + 55% Large Lad RR soybean, T4 = 35% MC 5300 corn + 65% Large Lad RR soybean, T5 = 65% MC 5300 corn + 35% Big Buck 6 soybean, T6 = 55% MC 5300 corn + 45% Big Buck 6 soybean, T7 = 45% MC 5300 corn + 55% Big Buck 6 soybean, T8 = 35% MC 5300 corn + 65% Big Buck 6 soybean, T9 = 65% Mastergraze Corn + 35% Large Lad RR soybean, T10 = 55% Mastergraze Corn + 45% Large Lad RR soybean, T11 = 45% Mastergraze Corn + 55% Large Lad RR soybean, T12 = 35% Mastergraze Corn + 65% Large Lad RR soybean, T13 = 65% Mastergraze Corn + 35% Big Buck 6 soybean, T14 = 55% Mastergraze Corn + 45% Big Buck 6 soybean, T15 = 45% Mastergraze Corn + 55% Big Buck 6 soybean, T16 = 35% Mastergraze Corn + 65% Big Buck 6 soybean)

CHAPTER 6

EFFECT OF INTERCROPPING OF CONVENTIONAL CORN WITH CONVENTIONAL FORAGE SOYBEAN OR VINING SOYBEAN WITH DIFFERENT SEEDING RATIOS ON BIOMASS YIELD, NUTRIENT YIELDS AND SILAGE QUALITY GROWN UNDER ORGANIC CONDITION

ABSTRACT

Previous research demonstrated that feeding forage blends produced through intercropping of corn and soybean could be beneficial for livestock. A field plot study was laid out using a randomized complete block design (RCBD) having three replicates to evaluate conventional organic corn hybrid, MC 5300 (OC) with conventional organic forage soybean, Viking 2265 (OS) or Vining soybean (VS) at five different seeding ratios to comprise nine different treatments [100:0:0 (T1); 0:100:0 (T2); 0:0:100 (T3); 50:50:0 (T4); 67:33:0 (T5); 33:67:0 (T6); 50:0:50 (T7); 67:0:33 (T8); and 33:0:67 (T9) of OC with OS and VS] to determine the optimal intercropping seeding ratio. Forages were hand harvested 110 d after planting, weighed, chopped, inoculated, packed into buckets, weighed, and ensiled for 90 d. Buckets were then re-weighed, opened, and forage samples collected and analyzed for nutrients composition. Fresh biomass yield was higher ($P < 0.01$) for T8 compared to the rest of the treatments (88.37, 31.34, 17.34, 85.07, 101.49, 68.06, 85.78, 107.00 and 74.86 T/ha for T1, T2, T3, T4, T5, T6, T7, T8 and T9 respectively). Dry matter yield was higher ($P < 0.01$) for T8 compared to T2, T3, T4, T6, T7, T8 and T9 with T1, and T5 being intermediate (32.22, 10.60, 5.93, 27.10, 33.83, 24.44, 29.31, 36.55 and 25.41 T/ha for T1, T2, T3, T4, T5, T6, T7, T8 and T9 respectively). Digestible DM yield was higher ($P < 0.01$) for T8 compared to T2, T3, T4, T6, T7 and T9 with T1, and T5 being intermediate (22.52, 7.95, 4.26, 19.33, 24.00, 17.35, 20.99, 25.69, and 17.99 T/ha for T1, T2, T3, T4, T5, T6, T7, T8 and T9 respectively). CP yield was lower ($P = 0.01$) for T3 with rest of the treatments being similar (2.49, 2.54, 1.26, 2.38, 2.72, 2.06, 2.16, 2.68, and 2.11 T/ha for T1, T2, T3, T4, T5, T6, T7, T8 and T9 respectively). Digestible NDF yield was higher ($P < 0.01$) for T8 compared to T2, T3, T6, and T9 with T1, T4, T5, and T7 being intermediate (6.02, 1.86, 1.24, 5.56, 6.49, 5.07, 6.46, 7.01, and 5.07 T/ha for T1, T2, T3, T4, T5, T6, T7, T8 and T9 respectively). Thirty h NDFD of fresh chopped forage was similar ($P > 0.05$) across the treatments (49.29%). Soybean grain yield was higher ($P < 0.01$) in T4 and T6 compared to T5, T7, T8 and T9 (3.06, 1.80, 3.38, 1.90, 0.53, and 2.36 T/ha for T4, T5, T6, T7, T8 and T9 respectively). Land equivalent ratio (LER) was higher ($P < 0.01$) for T4 (1.32) and T5 (1.31) compared to T7 (1.15), T8 (1.16) and T9 (1.11). Crude protein content was higher ($P < 0.01$) for T6 (9.64%) compared to T4 (8.96%), T5 (8.22%), T7 (8.20%), and T8 (7.94%). Starch content was higher for T4 (29.18%) compared to T9 (26.03%). Thirty hour neutral detergent fiber digestibility (NDFD) was higher ($P < 0.01$) for T4 (45.81%), T6 (47.41%) and T9 (46.19%) compared to T5 (43.86%) and T8 (43.38%). The production of forage blends through intercropping of corn and soybean has the potential to yield greater quantities of digestible nutrients compared to monocropping, grown under organic condition.

Key words: corn, forage soybean, silage yield, intercropping

INTRODUCTION

Forage yield and quality are the most concerned and main stream discussion in recent years because of skyrocketing prices of corn and soybean meal. Scientists and farmers are continuously trying to develop quality high yield forage programs through different means among which intercropping of cereals and legumes is in the forefront. Intercropping is the real-time growing of two or more crops on the same piece of land at the same time during the same growing season. The reason for intercropping is to obtain a higher yield per unit land area and time, and also unbiased and thoughtful use of available natural resources and inputs. Corn has been recognized as a major component in most intercropping systems in the world because of being an excellent energy source for both humans and livestock. The corn soybean cropping systems that dominate the upper Midwest are among the most productive in the world and contribute significantly to making the United States the world's largest producer of corn and soybeans (U.S. Department of Agriculture, 2015).

Intercropping is being encouraged as an improved alternative approach to conventional farming. However, it has been less practiced because of the difficulties of planting and harvesting (Martin et al., 1987). Intercropping involves competition for sun light, moisture and nutrients. It also restricts the herbicide options and complicates cultivation. However, the intercrop usually benefits from increased light interception, better root contact with more soil, increased microbial activity and can act as a defense to pests and weeds of the other crop. There is also evidence that suggests intercropping may benefit a non-legume, which needs nitrogen if the other crop is a legume, since legumes will fix nitrogen in the soil.

Corn is considered a major forage crop for intensive dairy farming in North America due to its high DM yield and energy content (Núñez et al., 2003). Despite that, corn has very low CP concentration ranging from 7.4 to 9.5 % (Sanchez et al., 2010) and high NDF concentration ranging from 44.7 to 63.3% (Núñez et al., 2001), which may limit the potential forage intake by dairy cattle when NDF exceeds 55% (Van Soest, 1965). This situation encouraged researchers to find innovative ideas to improve forage quality without losing DM yield. In order to improve forage quality, intercropping of corn and legumes has been evaluated, and reported not only similar total DM yield but also an increase in CP concentration by 1.9 to 2.7% (Herbert et al., 1984; Geren et al., 2008) and in CP yields per hectare by13.0 to 37.8% (Geren et al., 2008; Javanmard et al., 2009). Total NDF was reduced by 12.4 to 14.6% (Javanmard et al., 2009) and ADF was reduced by 7.5 to 7.7 % (Murphy et al., 1984; Demirel et al., 2009) in intercropped corn and legumes compared to monocropped corn.

Intercropping has considerably reduced the number of soybean leaves by 58%, leaf area index by 75% and phytomass at the start of seed filling by 78% (Maluleke et al., 2005). Soybean yields were concentrated by up to 90% in intercropping with corn in the equal row (Dalal, 1977). Thus, intercropping of corn and soybean with different row spaces and seeding ratios might affect the overall all biomass yield and silage quality. In this research, we hypothesized that corn intercropped with Vining soybean lines would produce more biomass and silage quality because of better utilization of natural resources and light due to the climbing nature of soybeans on corn.

OBJECTIVES

The objectives of this study were to compare intercropping of different seeding ratios of corn and soybean on biomass yield and nutrient yields, and compare final silage quality produced from intercropping of different seeding ratios of corn and soybean grown under organic condition.

MATERIALS AND METHODS

This research was conducted at Dairy Research and Training Facility at South Dakota State University, Brookings, SD during the 2015 crop season.

Field preparation

Soil preparation consisted of plowing, disking, leveling and layout. Field was prepared without addition of any chemical fertilizer, herbicides and pesticides. A soil sample was taken before planting the crop and after harvesting the crop to estimate the nutritional status of soil in the research area. A total of 27 plots having equal areas of 5.6 m^2 (2.3 m × 2.4 m) were prepared to apply the treatments.

Corn and soybean varieties

Masters Choice 5300, organic forage corn (OC) having 103 d of maturity is well known for strong emergence and seeding vigor for organic production and reduced tillage operation, has very good tonnage and bushels per acre with excellent nutrition. It has wide leaf, showy robust plant, excellent dual purpose white cob variety for livestock feed that drives performance (Masters Choice Seed Corn, Anna, IL).

Viking 2265, regular organic forage soybean (OS) is grown well when planted at late spring for seed, forage or cover crop. It is considered an all-time bestselling organic soybean because of consistent high yields, average protein and dark hilum feed grade soybean. It is medium tall (3 to 4 feet), bushy, very good lodging resistance and competes well with weeds. It has excellent emergence, high capacity for nitrogen fixation and phytopthora field tolerance (Johnny’s seed, Winslow, ME).

Vining soybean line (VS) was developed by a soybean breeder at South Dakota State University through intensive selection process from wild soybeans. Growth is indeterminate type and climbs the corn plant if planted together. Preliminary research showed very good potential forage soybean to increase CP content of silage (Plant Science Department, South Dakota State University).

Experimental design and treatments

A field plot experiment was conducted to measure forage yield, nutrients concentration and silage quality when intercropping MC 5300 corn (OC) with regular forage soybean, Viking 2265 (OS) and Vining (VS) soybean lines at different seeding ratios. A randomized complete block design (RCBD) with five different seeding ratios comprised nine treatments [100:0:0 (T1); 0:100:0 (T2); 0:0:100 (T3); 50:50:0 (T4); 67:33:0 (T5); 33:67:0 (T6); 50:0:50 (T7); 67:0:33 (T8); and 33:0:67 (T9) of OC with OS or VS] with three replicates was used to determine the optimal intercropping seeding ratio. We used MC 5300 corn at 86,487 seeds/ha, Viking 2265 and Vining soybean at 358, 302 seeds/ha to calculate the total counts of corn and soybean seeds required for each treatment per plot. Seeds of corn and soybean were planted manually. The final arrangements of treatments were as follows:

T1: 100% MC 5300 corn (C-C---C-C---C-C)

T2: 100% Viking 2265 forage soybean (S--S--S)

T3: 100% Vining forage soybean (S--S--S)

T4: 50% MC 5300 corn + 50% Viking 2265 forage soybean (C-S-S-C-- C-S-S-C)

T5: 67% MC 5300 corn + 33% Viking 2265 forage soybean (C-S-C-- C-S-C)

T6: 33% MC 5300 corn + 67% Viking 2265 forage soybean (S-C-S-- S-C-S)

T7: 50% MC 5300 corn + 50% Vining forage soybean (C-S-S-C-- C-S-S-C)

T8: 67% MC 5300 corn + 33% Vining forage soybean (C-S-C-- C-S-C)

T9: 33% MC 5300 corn + 67% Vining forage soybean (S-C-S-- S-C-S)

Where, C = corn, S = soybean, - = 22.86 cm, -- = 45.72 cm, and --- = 68.58 cm apart

Weeding, harvesting, ensiling, and sampling

Weeds were removed 3 times during the cropping season at 25 and 50 d by using small rotary tiller and manually at 75 d after planting. No irrigation was provided throughout the study period. Plant height of 20 corns and 20 soybeans were taken randomly from each plot a week before harvesting. Forage was hand harvested from center rows of plot at 115 d after planting and fresh biomass yield was recorded. Plants were chopped with locally made shredder, inoculated with Silo-King® plus at recommended rate, packed into plastic buckets, weighed, and ensiled for 90 d. Rest of the rows on each plot was kept, as such until grain was ready to harvest. At 130 d after planting, we counted total number of corn and soybean on each row and harvested seeds to estimate total corn and soybean grain yield, as well as, 100 seed test weight. After 90 d, buckets were re-weighed, opened, and samples of forage were collected.

Sample analyses

Fresh (0) and 90 d ensiled forage samples were analyzed for DM, CP,SP, ADF, NDF,ADIP, NDIP, Starch, NFC, NE_L, 6-C Sugar, EE, Nitrates, IVDMD, NDFD30, Lignin, Ash, NH_3-N, pH, Lactic acid, acetic acid, Butyric acid, Na, Mg, P, S, K, Ca, Cl, Mn, Fe, Cu and Zn (Analab, Inc., Fulton, IL). The AOAC (2006) was used to analyze DM (935.29), CP (990.03), SP (Krishnamoorthy et al., 1982), ADF (973.18), NDF (2002.04), ADIP (Goering and Van Soest, 1970; Goering et al., 1972), NDIP (2002.04 minus sulfite and 976.06), Starch (996.11, enzymatic method analyzed on RFA using Glucose Trinder), NFC (100- NDF – CP – Fat - EE), NE_L (NRC,2001), 6-C Sugar (Ethanol extract, HPLC with ELSD), EE (920.39), Nitrates (968.07), IVDMD (ANKOM technology -08/05), NDFD30 (ANKOM technology method 3), Lignin (973.18), Ash (942.05), NH_3-N (University of Wisconsin Extension SKU:A3769, MAP 4.3 adapted from USEPA 351.2 and ISO 11732), pH (981.12), Lactic acid (LC-GC Vol.

11 No. 10), Acetic Acid (LC-GC Vol. 11 No. 10), Butyric Acid (LC-GC Vol. 11 No. 10) and Minerals (Ca, P, Mg, K, Na: 985.01; S: 923.01; Cl: 915.01; Mn, Fe, Cu, ZN:985.01).

Estimation of land equivalent ratio

The ratio of area needed under sole cropping to that of intercropping at the same management level to produce an equivalent yield (Mead and Willey, 1980). Land equivalent ratio (LER), which is often considered as an indicator of intercropping benefit. The value of LER = 1 means the amount of land required for soybean and corn grown together is the same as that for soybean and corn grown in pure stand and there is no advantage to intercropping over pure cropping. LER >1 shows an advantage to intercropping, while numbers below 1 shows a disadvantage to intercropping over pure cropping. In order to study the performance of the intercropping, the following equation was used:

$$LER = (Y_{ic}/Y_{mc}) + (Y_{is}/Y_{ms})$$

Where, Y_{mc} and Y_{ms} are the sole crop yield of corn and soybean, respectively, Y_{ic} is the intercrop yield of corn, and Y_{is} is the intercrop yield of soybean.

Estimation of total nitrogen accumulated by the crop

Total nitrogen accumulated by the crops (T/ha) can be calculated as follows:

$$\text{Total N} = \Sigma\ (DMY \times N\ \%)$$

Where DMY is the yield of DM (T/ha) and N is the concentration of nitrogen in plant. Crude protein content of forage was used to calculate total nitrogen content. Once DMY per ha was multiplied by nitrogen percentage, we can get total nitrogen uptake by treatment forage on per ha basis.

Net return

$$\text{Net return (\$/ha)} = GI - (S + Mc + L + C + R + CI + Mi + I)$$

Where GI is gross income ($/ha), S is seed costs ($/ha), Mc is machinery expenses ($/ha), L is labor cost ($/ha), C is compost/manure cost ($/ha), and, R is rental land cost ($/ha), CI is crop insurance cost ($/ha), Mi is miscellaneous cost ($/ha), and I is interest on variable cost ($/ha).

Current price of grain and silage published on USDA livestock, poultry and grain market news as of 6th January, 2016 was used to estimate gross income from grain or silage. The prices of organic corn silage (35% DM), organic soybean silage (35% DM), organic corn, and organic soybean were $95.98, $141.23, $371.24, and $857.60 per ton, respectively. Respective 35% DM yield of corn forage and silage forage were used to calculate total gross income from silage blends on each treatment. Similarly, corn grain yield and soybean grain yield were used to calculate total income from grains on each treatment. Total cost of forage or grain production was calculated by using cost estimates formula for Iowa State developed by Plastina (2016). Total cost of forage production ($1,743.99/ha) includes seed cost ($320.84/ha), machinery cost ($345.95/ha), labor cost

$172.97/ha), compost cost ($160.62/ha), rental land cost ($ 657.30/ha), crop insurance ($30.15/ha), miscellaneous ($24.71/ha), and interest on variable cost ($31.46/ha).

Statistical analysis

Statistical analysis of all data were performed by using the PROC MIXED procedure of SAS subjected to least squares ANOVA (SAS Institute Inc., Cary, NC, Version 9.4) for a randomized complete block design (Steel and Torrie, 1980). Data were tested for heterogeneity of variances and statistical significance was declared at $P \leq 0.05$.

Model used for this experiment was as follows:

$Y_{ij} = \mu + T_i + B_j + + e_{ij}$

where,

Y_{ij} is the dependent variable

μ is the overall mean

T_i is the i_{th} effect of treatment (i = 1,2, ……..9)

B_j is the j_{th} effect of block (j = 1,2,3)

e_{ij} is the error term

RESULTS AND DISCUSSION

Temperature and rainfall patterns of crop growing season

The crop growing season of 2015 was normal in terms of temperature and rainfall (Table 6.1) when compared the average temperature and precipitation for the past 30 years. Thus, the 2015 crop year can be considered as very good crop year in terms of biomass and grain production of corn and soybean.

Yields of forage biomass, DM, and nutrients

Fresh biomass yield, 35% DM corrected yield, DM yield, and DM loss is presented in Table 6.2 and Figure 6.1. Overall biomass production was outstanding for all treatments compared to the previous year study. However, T8 produced greater ($P < 0.05$) amount of fresh biomass and 35% DM corrected biomass compared to T1, T2, T3, T4, T6, T7 and T9 with T5 being intermediate (88.37, 31.74, 17.34, 85.07, 101.49, 68.06, 85.78, 107.00, and 74.86 T/ha of fresh biomass yield; 92.06, 30.28, 16.95, 77.44, 96.67, 69.67, 69.83, 83.75, 104.42, and 72.62 T/ha of 35% DM corrected yield for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total DM yield was greater ($P < 0.05$) for T8 compared to T2, T3, T4, T6, T7 and T9 with T5 and T1 being intermediate (32.22, 10.60, 5.93, 27.10, 33.83, 24.44, 29.31, 36.55, and 25.42 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total DDM yield was greater ($P < 0.05$) for T5 and T8, lower for monocropped soybeans (T2 and T3) and other treatments being intermediate (22.52, 7.95, 4.26, 19.33, 24.00, 17.35, 20.99, 25.69, and 17.99 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total DM loss (T/ha) while ensiled was greater ($P < 0.05$)

for T1 compared to the rest of the treatments. Total CP yield was lower ($P < 0.05$) for T3 (monocropped Vining soybean) compared to rest of the treatments being similar (2.49, 2.54, 1.26, 2.38, 2.72, 2.06, 2.16, 2.68 and 2.11 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total NDF yield was higher ($P < 0.05$) for T7 and T8 compared to T2 and T3 with other treatment being intermediate (11.98, 3.82, 2.60, 10.98, 12.81, 9.83, 13.31, 14.85, and 10.55 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total DNDF yield was greater ($P < 0.05$) for T8 compared to monocropped soybeans (T2 and T3) with other treatments being intermediate (6.02, 1.86, 1.24, 5.56, 6.49, 5.07, 6.46, 7.01, and 5.07 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total starch yield was higher ($P < 0.05$) for T8 compared to T2, T3, T6 and T9 with other treatments being intermediates (11.50, 0.01, 0.01, 8.01, 11.36, 7.24, 5.28, 12.19, and 7.04 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total NFC yield was higher ($P < 0.05$) for T1, T5, and T8 compared to rest of the treatments (15.87, 2.95, 1.55, 12.04, 16.26, 11.03, 12.31, 16.87, and 11.23 T/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Total NE_L yield was greater for T5 and T8 compared to T2, T3, T4, T7 and T9 with T1 being intermediate (54909, 15528, 8011, 43745, 56349, 39548, 45928, 59347, and 40362 Mcal/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Milk yield estimated through Milk2006 (Shaver et al., 2006) was greater ($P < 0.05$) for T5, and T8 compared to rest of the treatments (43.8, 9.97, 5.33, 41.63, 50.75, 38.25, 44.38, 52.50, and 36.69 T/ha milk for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Woomer and Tungani (2003) stated that intercropping of 2 × 2 rows of corn and soybean resulted in 20% more light to the soybean when compared to the conventional intercropping pattern. Ennin et al. (2002) stated that 4% more sunlight received by crops in closer row arrangements of soybean and corn than in equally spaced 2 rows soybean: 2 rows maize. Then again, due to adverse competitive effects between the crops, intercropping can lead to a decline in yield of one or more of component crops (Willey et al., 1980). An intensive review paper published on intercropping by Ofori and Stern (1987) showed that on average, legume yield decreased by 52% of the monocrop yield, whereas the cereal yield was decreased by only 11% of monocrop yield.

Net return from silage and grain production

Net return from silage and grain production across the treatments is listed in Table 6.3. Net return from silage production was greater ($P < 0.05$) for T8 compared to T1, T2, T3, T4, T6, and T9 with T5, T7, and T8 being intermediate (7092.22, 2532.40, 649.17, 7440.70, 8977.78, 7074.73, 8189.39, 9837.49, and 7427.77 $/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). However, net return from grain was lower compared to net return from silage production. Net return from grain production was greater ($P < 0.05$) for T4 and T5 compared to T1, T2, T3, T6, T7 and T9 with T8 being intermediate (4190.12, 2748.81, 2296.15, 5273.51, 5530.92, 4437.98, 4294.32, 4897.73, and 3873.73 $/ha for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively).

Nitrogen accumulated by plants

Nitrogen accumulation by treatment forage from the soil is presented in Table 6.3.Total Nitrogen accumulated by plants was lower ($P < 0.05$) in T3 (0.20 T/ha) compared to rest of the treatments (0.39 T/ha). This was because of lower biomass production in T3 compared to other treatments.

Grain yields of corn and soybean

Grain yield of corn and soybean is presented in Table 6.3. Corn grain yield was greater ($P < 0.05$) for T1, T5 and T8 compared to T4, T6, T7, and T9 (15.98, 11.84, 15.44, 8.84, 11.89, 16.66, 9.68 T/ha for T1, T4, T5, T6, T7, T8, and T9 respectively). Soybean grain yield was greater ($P < 0.05$) for monocropped soybeans (T2, and T3) compared to intercropped corn and soybean treatments of T4, T5, T6, T7, T8, and T9 (5.24, 4.71, 3.06, 1.80, 3.38, 1.90, 0.53, and 2.36 T/ha of soybean grain for T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Matusso et al. (2014) reported that corn and soybean intercropped at 2:2 ratio produced significantly higher stover and grain yields of corn compared to sole or other ratio. Similarly, soybean yield was reduced by 52 to 81% in two different growing seasons. Intercropping considerably reduced the final stand count of corn by 3.2% and that of the legumes by 10.6% compared to the sole crops (Bekele et al., 2013). Separating corn and soybean with a small grain strip could decrease competition for soybean and improve overall yield (Iragavarapu and Randall, 1996).

Land equivalent ratio

Calculated value of LER based on grain production for different treatments is presented in Table 6.3. Land equivalent ratio was greater for T4 and T5 compared to T7, T8, and T9 with T6 being intermediate (1.32, 1.31, 1.20, 1.15, 1.16, and 1.11 LER for T4, T5, T6, T7, T8, and T9 respectively). Since LER value is more than 1, all intercropping treatments were superior in terms of grain production over monocropping of corn or soybean.

Plant heights

Average plant height of corn and soybean for different treatments is presented in Table 6.3 Average corn height was greater ($P < 0.05$) for T5, T8, and T9 compared to T6 with T1, T4, and T7 being intermediate (226.80, 232.46, 245.94, 213.86, 226.98, 240.53, 244.24 cm corn height for T1, T4, T5, T6, T7, T8, and T9 respectively). Average soybean height was greater ($P < 0.05$) for Vining type soybean (195.79 cm for T3, T7, T8, and T9) compared to Viking 2265 soybean (98.58 cm for T2, T4, T5 and T6).

Nutrient composition of fresh chopped samples

Nutrient compositions of fresh chopped samples are presented in Table 6.4. Dry matter content of fresh samples was similar ($P > 0.05$) across the treatments (34%). Among the intercropped treatments, T4, T6, and T9 were greater ($P < 0.05$) in CP content compared to T7, and T8 with T5 being intermediate (8.74, 8.06, 8.40, 7.38, 7.32, and 8.31% CP for T4, T5, T6, T7, T8, and T9 respectively). Among monocropped treatments, T2 was greater in CP concentration compared to T3 and T1 (7.67, 24.05, and 21.21% CP for T1, T2, and T3 respectively). Soluble protein concentration was greater ($P < 0.05$) for T2 and T3 compared to rest of the treatments (27.13, 39.55, 44.55, 27.47, 26.87, 26.55, 32.59, 24.87, and 30.53% SP for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). The NDF content of fresh sample was higher for T8 compared to T1, T2, and T5 with T3, T4, T6, T7, and T9 being intermediate (37.54, 35.73, 43.33, 40.42, 37.73, 40.80, 45.14, 40.95, and 41.53% NDF for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Lignin content was higher for monocropped soybean (T2, and T3) compared to monocropped corn (T1) and intercropped treatments (T4, T5, T6, T7, T8, and T9). Starch content of fresh forage sample was higher for T1, T5, and T8 compared to T3, T4, and T7 with other being intermediate (35.30, 0.09, 0.09, 29.76, 33.73, 29.11, 19.65, 33.02, and 27.64% starch respectively for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). The NFC level was greater in T1, T4, T5, T6, T8, and T9 compared to T2, T3 and T7 (48.96, 27.94, 26.53, 44.56, 47.18, 44.62, 42.14, 45.89, and 44.13% NFC for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Similarly, sugar level was lower for monocropped soybean treatments (T2 and T3) compared to monocropped corn (T1) and intercropped treatments (T4, T5, T6, T7, T8, and T9). The NE_L content of fresh sample was higher in monocropped corn (T1) compared to monocropped soybean (T2, and T3) and T7 with other being intermediate (1.70, 1.48, 1.37, 1.61, 1.68, 1.61, 1.57, 1.61, and 1.59 Mcal/kg for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Fiber digestibility for 30 h (NDFD30) of fresh chopped samples was similar across the treatments (49.17%). pH value of fresh samples was greater for monocropped soybeans (T2 and T3) compared to monocropped corn (T1) and intercropped treatments (4.87, 5.40, 5.33, 4.83, 4.83, 5.03, 4.97, 4.80, and 4.90 pH value for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively).

Mineral composition of fresh chopped samples

Mineral composition of freshly chopped samples among the different treatments is listed in Table 6.5. Concentrations of Ca, P, Mg, K, Na, S, Mn Fe, Cu and Zn were higher in monocropped soybeans (T2 and T3) compared to monocropped corn (T1) and intercropped treatments. However, concentration of Cl was lower in monocropped soybeans compared to intercropped treatments. Intercropping of corn with soybean increased concentration of most of the minerals in this study. Thus, soybeans are a good source of minerals for dairy cows.

Nutrient composition of silage

Nutrient composition of silage produced among the different treatments is presented in Table 6.6. The CP content of silage was greater in monocropped soybeans (T2 and T3) compared to monocropped corn with intercropped crops being intermediate (7.87, 23.17, 21.00, 8.96, 8.22, 9.64, 8.20, 7.94, and 9.26% CP for silage produced through T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Soluble protein and NDF content was lower for T2 (42.47% SP and 36.58% NDF) compared to rest of the treatments (46.74% SP and 41.36% NDF). Lignin content of the silage was greater for T2 and T3 (monocropped soybeans) compared to rest of the treatments (2.56, 9.65, 8.50, 2.32, 2.40, 2.28, 2.36, 2.50, and 2.40 % for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Starch content was lower for monocropped soybeans (T2 and T3) compared to monocropped corn and intercropped treatments (26.60, 0.09, 0.17, 29.18, 29.73, 27.66, 29.33, 28.55, and 26.03% starch for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). The NFC content of silage follows the same pattern as starch content among the treatments. The NFC content was lower for monocropped soybean treatments (T2 and T3) compared to mon0cropped corn (T1) and intercropped treatments (44.46, 28.83, 27.80, 45.00, 45.98, 43.08, 45.05, and 42.97% NFC for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). The estimated NE_L was similar among monocropped corn (T1) and intercropped treatments but lower for monocropped soybeans of T2 and T3 (1.63,1.39, 1.34, 1.68, 1.68, 1.68, 1.68, 1.65, and 1.65 Mcal/kg of silage DM for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Ash content of the silage was greater for monocropped soybeans (T2 and T3) compared to rest of the treatments (3.44, 9.66, 8.87, 3.83, 3.64, 3.99, 3.68, 3.67, and 4.02 % for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively). Fiber digestibility for 30 h (NDFD) was greater for T3 compared to rest of the treatment. pH value of the silage was higher for monocropped soybeans (T2 and T3) compared to monocropped corn (T1) and intercropped treatments (4.18, 4.43, 4.31, 3.96, 4.06, 3.93, 4.10, 4.13, and 3.99 pH for T1, T2, T3, T4, T5, T6, T7, T8, and T9 respectively).

Mineral composition of silage

Mineral composition of silage produced from different treatments is presented in Table 6.7. Similar to nutrient composition of fresh sample, monocropped soybeans (T2 and T3) were greater in Ca, P, Mg, K, Na, S, Mn, Fe, Cu, Zn content except Cl compared to monocropped corn and intercropped treatments. Cl content was higher in intercropped treatment s (T7 and T8) compared to monocropped soybean (T2 and T3) with monocropped corn (T1), T4, T5, and T6 being intermediate. Again, mineral composition data revealed that forage soybean is excellent source of most of the minerals for dairy cows compared to corn silage.

CONCLUSIONS

Fresh biomass yield, dry matter yield, and net return from silage production were greater for MC 5300 organic corn and Vining soybean combination at 67:33 seeding ratio compared to rest of the treatments. Crude protein and starch content was greater for

50:50 seeding ratio of MC 5300 organic corn and Viking 2265 organic soybean combination compared to other combination and seeding ratios. Nitrogen accumulation by treatment forages was lowest in monocropping of Vining soybean compared to rest of the treatments. Land equivalent ratio was greater for MC 5300 organic corn and Viking 2265 soybean combination at 67:33 or 50:50 seeding ratios respectively. The production of forage blends through intercropping of corn and soybean has the potential to yield greater quantities of digestible nutrients.

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Table 6.1. Climatic conditions during the 2015 growing season[1]

Months	Temperature, °C		Precipitation, mm	
	Mean	Deviation[2]	Total	Deviation[2]
April	8.3	1.9	7.6	-49.6
May	12.8	-0.7	119.1	10.8
June	19.4	0.5	58.4	-52.7
July	21.7	0.4	100.6	20.3
August	19.4	-0.5	176.8	101.6
September	18.3	3.2	43.7	-35.4
October	10.0	2.4	29.5	-15.7
November	3.3	4.3	33.5	15.2

[1] Data collected from a weather station located at South Dakota State University approximately 3 km from the plots.

[2] Deviation = actual minus 30 year monthly average.

Table 6.2. Forage and nutrient yields (T/ha unless indicated) when intercropping of corn with soybean at different seeding ratios grown under organic condition

	Treatments[1]									
Yields	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
Fresh biomass	88.37^{bc}	31.74^{e}	17.34^{e}	85.07^{bc}	101.49^{ab}	68.06^{d}	85.78^{bc}	107.00^{a}	74.86^{cd}	6.74
35% DM	92.06^{ab}	30.28^{d}	16.95^{d}	77.44b^{c}	96.67^{ab}	69.83^{c}	83.75^{bc}	104.42^{a}	72.62^{c}	6.26
DM[2]	32.22^{ab}	10.60^{c}	5.93^{c}	27.10^{b}	33.83^{ab}	24.44^{b}	29.31^{b}	36.55^{a}	25.42^{b}	2.19
DM loss	0.50^{a}	0.09^{c}	0.28^{b}	0.11^{bc}	0.22^{bc}	0.26^{b}	0.25^{bc}	0.16^{bc}	0.24^{bc}	0.07
DDM[3]	22.52^{b}	7.95^{e}	4.26^{f}	19.33^{cd}	24.00^{a}	17.35^{d}	20.99^{bc}	25.69^{a}	17.99^{d}	0.91
CP[4]	2.49^{a}	2.54^{a}	1.26^{b}	2.38^{a}	2.72^{a}	2.06^{a}	2.16^{a}	2.68^{a}	2.11^{a}	0.24
NDF[5]	11.98^{ab}	3.82^{c}	2.60^{c}	10.98^{ab}	12.81^{ab}	9.83^{b}	13.31^{a}	14.85^{a}	10.55^{ab}	1.04
DNDF[6]	6.02^{ab}	1.86^{c}	1.24^{c}	5.56^{ab}	6.49^{ab}	5.07^{b}	6.46^{ab}	7.01^{a}	5.07^{b}	0.53
Starch	11.50^{ab}	0.01^{d}	0.01^{d}	8.01^{bc}	11.36^{ab}	7.24^{c}	5.28^{c}	12.19^{a}	7.04^{c}	1.41
NFC[7]	15.89^{a}	2.95^{c}	1.55^{c}	12.04^{b}	16.26^{a}	11.03^{b}	12.31^{b}	16.87^{a}	11.23^{b}	1.31
NE$_{L}$[8] yield, Mcal/ha	54909^{ab}	15528^{c}	8011^{d}	43745^{b}	56349^{a}	39548^{b}	45928^{b}	59347^{a}	40362^{b}	4136
Milk[9]	43.8^{b}	9.97^{d}	5.33^{d}	41.63^{bc}	50.75^{a}	38.25^{c}	44.38^{b}	52.50^{a}	36.69^{c}	2.34

^{a,b,c,d,e}Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean

[2] Dry matter; [3] Digestible dry matter; [4] Crdue protein; [5] Neutral detergent fiber; [6] Digestible neutral detergent fiber; [7] Non fiber carbohydrate; [9] Estimated net energy for lactation through NRC (2001); [9] Milk yield potential of forage estimated through MILK2006

Table. 6.3. Grain yields, N accumulation, land equivalent ratio, net return and plant height when intercropping of corn with soybean at different seeding ratios grown under organic condition

	Treatments[1]									
Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
Corn grain yield, T/ha	15.98^{a}	-	-	11.84^{b}	15.44^{a}	8.84^{c}	11.89^{b}	16.66^{a}	9.68^{c}	0.44
Soybean grain yield, T/ha	-	5.24^{a}	4.71^{a}	3.06^{b}	1.80^{b}	3.38^{b}	1.90^{c}	0.53^{d}	2.36^{c}	0.23
N accumulation, T/ha	0.40^{a}	0.41^{a}	0.20^{b}	0.38^{a}	0.44^{a}	0.33^{a}	0.35^{a}	0.43^{a}	0.34^{a}	0.04
Land equivalent ratio	-	-	-	1.32^{a}	1.31^{a}	1.20^{ab}	1.15^{b}	1.16^{b}	1.11^{b}	0.05
Net return from silage, $/ha	7092.22^{b}	2532.40^{c}	649.17^{c}	7440.70^{b}	8977.78^{ab}	7074.73^{b}	8189.39^{ab}	9837.49^{a}	7427.77^{b}	730.34
Net return from grain, $/ha	4190.12^{bc}	2748.81^{d}	2296.15^{d}	5273.51^{a}	5530.92^{a}	4437.98^{bc}	4294.32^{bc}	4897.73^{ab}	3873.73^{c}	276.09
Corn plant height, cm	226.80^{ab}	-	-	232.46^{ab}	245.94^{a}	213.86^{b}	226.98^{ab}	240.53^{a}	244.24^{a}	12.66
Soybean plant height, cm	-	110.90^{b}	194.80^{a}	96.42^{b}	98.40^{b}	88.60^{b}	177.76^{a}	207.10^{a}	203.48^{a}	21.95

^{a,b,c,d}Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean

Table 6.4. Nutrient composition of fresh chopped forage when intercropping of corn with soybean at different seeding ratios grown under organic condition

	Treatments[1]									
Nutrients composition	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
DM, %	36.46	32.39	34.56	32.05	33.66	35.85	34.30	35.20	33.99	1.82
--% of DM unless otherwise indicated--										
CP	7.67^{cd}	24.05^{a}	21.21^{b}	8.74^{c}	8.06^{cd}	8.40^{c}	7.38^{d}	7.32^{d}	8.31^{c}	0.28
SP[2], % of CP	27.13^{bc}	39.55^{a}	44.55^{a}	27.47^{bc}	26.87^{bc}	26.55^{bc}	32.59^{b}	24.87^{c}	30.53^{bc}	2.30
ADIP[3]	0.25^{de}	2.05^{a}	1.41^{b}	0.36^{cd}	0.29^{cde}	0.40^{c}	0.19^{e}	0.36^{cd}	0.39cd	0.05
NDIP[4]	0.87^{bc}	0.12^{d}	0.34^{cd}	1.21^{ab}	1.01^{ab}	1.31^{a}	0.62^{c}	0.90^{abc}	1.03^{abc}	0.14
ADF	21.97^{c}	31.48^{a}	35.35^{a}	24.65^{bc}	22.70^{c}	24.89^{bc}	27.41^{b}	24.95^{bc}	25.62^{bc}	1.62
NDF	37.54^{bc}	35.73^{c}	43.33^{ab}	40.42^{abc}	37.73^{bc}	40.80^{abc}	45.14^{a}	40.95^{abc}	41.53^{ab}	2.37
Lignin	2.00^{c}	9.06^{a}	8.49^{a}	2.36^{bc}	2.17^{bc}	2.52^{bc}	2.81^{b}	2.55^{bc}	2.59^{bc}	0.25
Starch	35.30^{a}	0.09^{c}	0.09^{c}	29.76^{ab}	33.73^{a}	29.11^{ab}	19.65^{b}	33.02^{a}	27.64^{ab}	3.90
NFC[5]	48.96^{a}	27.94^{c}	26.53^{c}	44.56^{a}	48.18^{a}	44.62^{a}	42.14^{b}	45.89^{a}	44.13^{a}	2.25
Sugar	7.62^{a}	1.20^{c}	3.96^{b}	7.21^{a}	7.10^{a}	6.83^{a}	8.37^{a}	6.54^{a}	6.55^{a}	0.65

EE	2.55^{bc}	5.50^{a}	2.97^{b}	2.52^{bc}	2.45^{c}	2.81^{bc}	2.14^{c}	2.33^{c}	2.32	0.16
NE_L, Mcal/kg	1.70^{a}	1.47^{bc}	1.36^{c}	1.62^{ab}	1.67^{ab}	1.61^{ab}	1.57^{bc}	1.62^{ab}	1.59^{abc}	0.04
NE_M, Mcal/kg	1.51^{a}	1.32^{b}	1.18^{c}	1.46^{a}	1.51^{a}	1.46^{a}	1.41^{ab}	1.45^{a}	1.43^{a}	0.04
NE_G, Mcal/kg	0.93^{a}	0.76^{b}	0.62^{c}	0.87^{a}	0.92^{a}	0.87^{a}	0.85^{ab}	0.87^{a}	0.86^{a}	0.04
Ash	4.14^{b}	6.88^{a}	6.29^{a}	4.96^{b}	4.59^{b}	4.66^{b}	3.82^{b}	4.40^{b}	4.73	0.45
IVDMD[6]	73.21^{a}	74.33^{a}	70.16^{ab}	71.55^{ab}	73.13^{a}	71.30^{ab}	66.23^{b}	70.49^{ab}	69.32^{ab}	1.93
IVTD[7]	81.33^{a}	81.57^{a}	77.47^{ab}	80.07^{ab}	81.42^{a}	80.11^{a}	76.77^{b}	78.29^{ab}	78.40^{ab}	1.57
NDFD[8]	50.26	48.34	48.17	50.72	51.01	51.56	48.43	47.14	47.95	1.66
NH_3-N, ppm	949.67^{a}	202.00^{d}	204.56^{cd}	898.00^{ab}	654.67^{ab}	764.33^{ab}	476.00^{bc}	882.33^{ab}	817.33^{ab}	156.35
PH	4.87^{c}	5.40^{a}	5.33^{ab}	4.83^{c}	4.83^{c}	5.03^{bc}	4.97^{c}	4.80^{c}	4.90^{c}	0.11
Lactic acid	1.61^{a}	0.61^{b}	1.13^{ab}	1.61^{a}	1.58^{a}	1.37^{ab}	0.84^{b}	1.18^{ab}	1.72^{a}	0.25
Acetic acid	0.37^{b}	1.99^{a}	0.53^{b}	0.25^{b}	0.17^{b}	0.34^{b}	0.25^{b}	0.25^{b}	0.08^{b}	0.24

[a,b,c,d,e] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean

[2] Soluble protein; [3] Acid detergent insoluble protein; [4] Neutral detergent insoluble protein; [5] Non fiber carbohydrate; [6] In vitro dry matter digestibility; [7] In vitro true digestibility [8] In vitro neutral detergent fiber digestibility for 30 h

Table 6.5. Mineral composition (% of DM unless noted) of fresh chopped forage when intercropping of corn with soybean at different seeding ratios grown under organic condition

	Treatments[1]									
Minerals composition	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
Ca	0.18^{d}	1.09^{a}	0.88^{b}	0.26^{cd}	0.22^{cd}	0.31^{c}	0.24^{cd}	0.18^{d}	0.29^{c}	0.04
P	0.23^{bc}	0.38^{a}	0.36^{a}	0.21^{c}	0.22^{c}	0.25^{b}	0.22^{c}	0.21^{c}	0.24^{bc}	0.01
Mg	0.18^{b}	0.39^{a}	0.36^{a}	0.21^{b}	0.18^{b}	0.20^{b}	0.19^{b}	0.17^{b}	0.20	0.02
K	1.01^{b}	1.96^{a}	1.96^{a}	1.10^{b}	1.10^{b}	1.21^{b}	1.11^{b}	1.03^{b}	1.19^{b}	0.10
Na	0.01^{b}	0.04^{a}	0.04^{a}	0.01^{b}	0.02^{b}	0.02^{b}	0.02^{b}	0.01^{b}	0.02^{b}	0.00
Cl	0.17^{b}	0.05^{b}	0.06^{b}	0.29^{ab}	0.24^{ab}	0.23^{ab}	0.28^{ab}	0.32^{a}	0.33^{a}	0.06
S	0.05^{d}	0.20^{a}	0.18^{b}	0.06^{cd}	0.06^{cd}	0.06^{cd}	0.05^{d}	0.05^{d}	0.07^{c}	0.01
Mn, ppm	18.00^{c}	48.00^{a}	42.67^{a}	22.67^{bc}	21.00^{bc}	26.00^{b}	23.67^{bc}	19.00^{c}	25.33^{b}	2.00
Fe, ppm	93.33^{c}	329.67^{a}	305.33^{b}	107.00^{bc}	96.67^{c}	146.33^{b}	118.67^{bc}	83.67^{c}	145.33^{b}	14.17
Cu, ppm	3.00^{d}	9.67^{a}	7.00^{b}	4.00^{cd}	3.00^{d}	4.33^{c}	2.67^{d}	3.33^{cd}	3.67^{cd}	0.42
Zn, ppm	28.00^{bc}	41.00^{a}	37.67^{ab}	26.00^{c}	28.67^{abc}	37.00^{ab}	28.00^{bc}	31.33^{abc}	26.67^{c}	3.38

[a,b,c,d] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean

Table 6.6. Nutrient composition of ensiled forage when intercropping of corn with soybean at different seeding ratios grown under organic condition

	Treatments[1]									
Nutrient	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
DM%	34.02^{a}	30.54^{c}	33.11^{a}	32.35^{a}	31.50^{bc}	34.53^{a}	33.83^{a}	32.39^{ab}	32.90^{ab}	0.89
……………………..……………..……………………...% of DM unless noted……………………………..……………………………										
CP	7.87^{e}	23.17^{a}	21.00^{b}	8.96^{de}	8.22^{de}	9.64^{c}	8.20^{de}	7.94^{de}	9.26^{cd}	0.41
SP[2], % of CP	46.36^{a}	42.47^{b}	47.40^{a}	45.59^{a}	47.52^{a}	46.14^{a}	46.42^{a}	47.21^{a}	47.25^{a}	0.91
ADIP[3]	0.35^{b}	1.26^{a}	1.32^{a}	0.35^{b}	0.34^{b}	0.38^{b}	0.34^{b}	0.34^{b}	0.38^{b}	0.03
NDIP[4]	0.87^{c}	2.79^{a}	2.61^{b}	0.89^{c}	0.82^{c}	0.95^{c}	0.84^{c}	0.82^{c}	0.95^{c}	0.05
ADF	23.92^{b}	34.21^{a}	36.21^{a}	22.38^{b}	22.78^{b}	22.92^{b}	22.87^{b}	23.53^{b}	23.63^{b}	0.91
NDF	42.86^{a}	36.58^{b}	42.00^{a}	40.13^{a}	40.32^{a}	40.91^{a}	40.89^{a}	41.64^{a}	42.09^{a}	1.30
Lignin	2.56^{c}	9.65^{a}	8.50^{b}	2.32^{c}	2.40^{c}	2.28^{c}	2.36^{c}	2.50^{c}	2.40^{c}	0.16
Starch	26.60^{ab}	0.09^{c}	0.17^{c}	29.18^{ab}	29.73^{a}	27.66^{ab}	29.33^{ab}	28.55^{ab}	26.03^{b}	1.35
NFC[5]	44.46^{a}	28.83^{b}	27.80^{b}	45.00^{a}	45.98^{a}	43.08^{a}	45.40^{a}	45.05^{a}	42.97^{a}	1.23

Sugar	3.69^{ab}	3.89^{ab}	5.94^{a}	3.89^{ab}	3.04^{b}	3.82^{ab}	3.48^{b}	3.51^{b}	4.61^{ab}	0.95
EE	2.23^{e}	4.54^{a}	2.92^{c}	2.95^{bc}	2.65^{cd}	3.32^{b}	2.66^{cd}	2.50^{de}	2.60^{cd}	0.14
NE$_L$, Mcal/kg	1.63^{a}	1.39^{b}	1.34^{b}	1.68^{a}	1.68^{a}	1.68^{a}	1.68^{a}	1.65^{a}	1.65^{a}	0.02
NE$_M$, Mcal/kg	1.48^{a}	1.21^{b}	1.15^{c}	1.50^{a}	1.50^{a}	1.50^{a}	1.50^{a}	1.48^{a}	1.48^{a}	0.02
NE$_G$, Mcal/kg	0.88^{a}	0.66^{b}	0.60^{b}	0.93^{a}	0.93^{a}	0.93^{a}	0.90^{a}	0.90^{a}	0.90^{a}	0.02
Ash	3.44^{d}	9.66^{a}	8.87^{b}	3.83^{cd}	3.64^{cd}	3.99^{c}	3.68^{cd}	3.67^{cd}	4.02^{c}	0.19
IVDMD[6]	70.03^{c}	75.09^{a}	73.23^{ab}	71.49^{bc}	70.94^{bc}	71.05^{bc}	71.44^{bc}	70.21^{c}	70.87^{bc}	1.18
IVTD[7]	75.83^{b}	79.50^{a}	78.99^{a}	78.20^{a}	77.36^{ab}	78.49^{a}	77.50^{ab}	76.42^{b}	77.34^{ab}	1.05
NDFD[8]	43.71^{c}	43.97^{c}	50.36^{a}	45.81^{b}	43.86^{c}	47.41^{b}	45.07^{bc}	43.38^{c}	46.19^{bc}	1.30
NH$_3$-N, ppm	1215.00^{ab}	1026.89^{b}	832.48^{c}	1324.78^{ab}	1249.33^{ab}	1383.89^{a}	1244.67^{ab}	1236.89^{ab}	1379.33^{a}	118.69
PH, scale	4.18^{b}	4.43^{a}	4.31^{a}	3.96^{c}	4.06^{c}	3.93^{c}	4.10^{b}	4.13^{b}	3.99^{c}	0.05
Lactic acid	3.94^{b}	3.10^{c}	4.94^{a}	4.40^{ab}	4.04^{b}	4.35^{ab}	4.01^{b}	4.13^{ab}	4.22^{ab}	0.30
Acetic acid	0.85^{d}	3.20^{a}	1.75^{b}	1.07^{cd}	1.17^{cd}	1.26^{bc}	1.08^{cd}	0.91^{d}	1.13^{cd}	0.12

[a,b,c,d,e]Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1]T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean

[2]Soluble protein; [3]Acid detergent insoluble protein; [4]Neutral detergent insoluble protein; [5]Non fiber carbohydrate; [6]In vitro dry matter digestibility; [7]In vitro true digestibility [8]In vitro neutral detergent fiber digestibility for 30 h

Table 6.7. Mineral composition (% of DM unless noted) of ensiled forage when intercropping of corn with soybeans at different seeding ratios under organic condition

	Treatments[1]									
Minerals composition	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM
Ca	0.20^{d}	1.13^{a}	0.81^{b}	0.26^{d}	0.22^{d}	0.32^{c}	0.24^{d}	0.21^{d}	0.29^{cd}	0.02
P	0.23^{c}	0.40^{a}	0.38^{a}	0.25^{bc}	0.23^{c}	0.27^{b}	0.23^{c}	0.23^{c}	0.26^{b}	0.01
Mg	0.19^{de}	0.42^{a}	0.38^{b}	0.21^{cd}	0.18^{e}	0.21^{cd}	0.20^{de}	0.19^{e}	0.22^{cd}	0.02
K	1.10^{c}	2.04^{a}	1.95^{a}	1.13^{c}	1.11^{c}	1.23^{b}	1.11^{c}	1.13^{c}	1.24^{b}	0.07
Na	0.03^{c}	0.05^{a}	0.05^{a}	0.03^{c}	0.03^{c}	0.04^{bc}	0.03^{c}	0.03^{bc}	0.04^{b}	0.00
Cl	0.20^{b}	0.04^{c}	0.05^{c}	0.25^{b}	0.23^{b}	0.23^{b}	0.27^{ab}	0.32^{a}	0.32^{a}	0.04
S	0.06^{d}	0.23^{a}	0.20^{b}	0.07^{c}	0.07^{cd}	0.08^{c}	0.07^{cd}	0.06^{d}	0.08^{c}	0.00
Mn, ppm	19.67^{d}	51.56^{a}	39.86^{b}	22.00^{d}	19.67^{d}	27.22^{c}	24.00^{cd}	21.00^{d}	25.67^{cd}	2.33
Fe, ppm	118.00^{d}	338.00^{a}	249.36^{b}	120.33^{d}	108.89^{d}	167.78^{c}	149.44^{cd}	115.89^{d}	181.78^{c}	12.33
Cu, ppm	3.44^{d}	9.11^{a}	7.38^{b}	3.89^{cd}	3.33^{d}	3.44^{d}	3.22^{d}	3.89^{d}	4.33^{c}	0.30
Zn, ppm	26.67^{bc}	36.00^{a}	31.83^{ab}	26.00^{bc}	26.33^{bc}	33.11^{ab}	24.89^{c}	26.44^{bc}	26.44^{bc}	2.25

^{a,b,c,d,e}Least squares means within the same row without a common superscript differ ($P < 0.05$)

[1] T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean

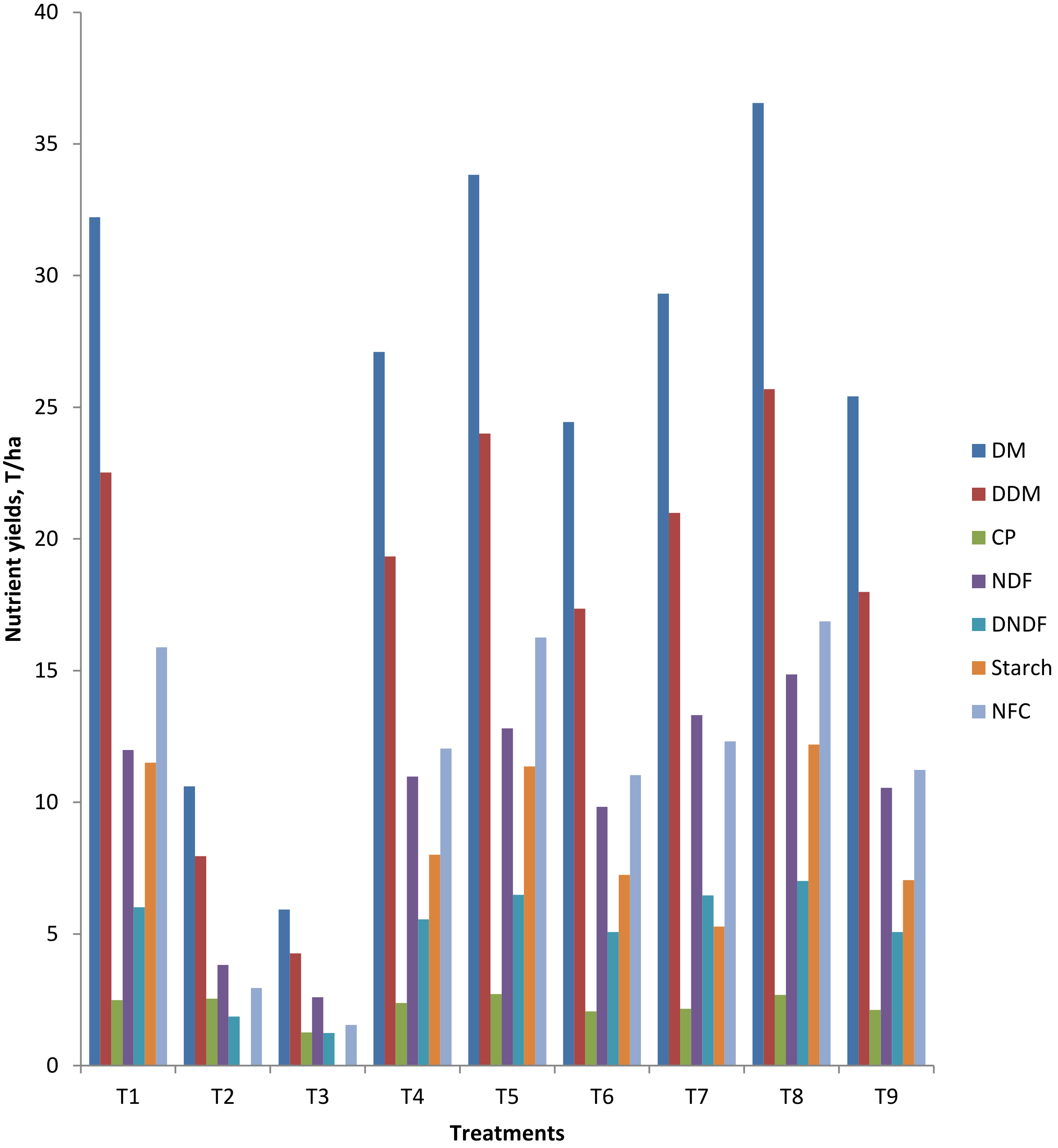

Figure 6.1. Nutrient yields of forage when intercropping of corn with soybean at different seeding ratios grown under organic condition (T1 = 100% MC 5300 corn, T2 = 100% Viking 2265 soybean, T3 = Vining soybean, T4 = 50% MC 5300 corn + 50% Viking 2265 soybean, T5 = 67% MC 5300 corn + 33% Viking 2265 soybean, T6 = 33% MC 5300 corn + 67% Viking soybean, T7 = 50% MC 5300 corn + 50% Vining soybean, T8 = 67% MC 5300 corn + 33% Vining soybean, T9 = 33% MC 5300 corn + 67% Vining soybean)

CHAPTER 7

RESPONSE OF ROW CROPPING OF MIXED SEEDS OF CORN AND SOYBEAN AT DIFFERENT SEEDING RATIOS ON FORAGE YIELD, NUTRIENT YIELDS AND QUALITY GROWN UNDER ORGANIC CONDITION

ABSTRACT

A field plot study was laid out using a randomized complete block design (RCBD) with three replicates to evaluate two organic corn hybrids [MC 5300 (OC) and BMR grazing corn (Masters Choice Mastergraze, MG)] with two organic soybeans [Viking 2265 (OS) and Vining (VS)] at four seeding ratios (R1 = 65:35; R2 = 55:45; R3 = 45:55, and R4 = 35:65 of corn and soybean respectively) in terms of forage yield, nutrient yields and quality. Forage was hand harvested at 101 d (MG corn with both soybeans) and 116 d (OC corn with both soybeans) after planting during the 2015 growing season, chopped, inoculated, packed into buckets, weighed, and ensiled for 90 d. Buckets were then re-weighed, opened, and forage samples collected and analyzed for nutrient composition. No interaction of corn × soybean × seeding ratio was detected for biomass yield and nutrient yields. The main effect of corn for dry matter yield (DMY) was greater ($P < 0.05$) for OC compared to MG (27.73 and 19.90 T/ha for OC and MG, respectively), while main effect of soybean for DMY was similar ($P > 0.05$, 23.77 and 23.86 T/ha for OS and VS, respectively). Main effect of seeding rate on DMY was higher ($P < 0.05$) for R1 and R2 compared to R3 and R4 (25.38, 24.48, 21.81 and 23.59 T/ha for R1, R2, R3 and R4, respectively). Yields of digestible dry matter (DDM; 19.55 and 13.67 T/ha) and CP (2.40 and 2.12 T/ha) were greater ($P < 0.05$) for OC compared to MG corn, similar (P

> 0.05) for both soybean (DDM; 16.65 and 16.57 T/ha and CP; 2.33 and 2.19T/ha for OS and VS respectively) and higher ($P < 0.05$) DDM for R1 and R2 compared to R3 and R4 (17.70, 17.08,15.13 and 16.54 T/ha for R1, R2, R3, and R4, respectively). Yield of starch (7.78 and 2.45 T/ha for OC and MG) and 30 h NDF digestibility (NDFD30; 44.47 and 52.49 % for OC and MG) for main effect of corn were different ($P < 0.05$), while similar ($P > 0.05$) for main effect of soybean (starch yield; 5.25 and 4.98 T/ha; NDFD30; 48.58 and 48.38% for OS and VS, respectively). The combination of OC corn either with OS or VS soybean at the ratio of R1 or R2 resulted in the greatest yield of DM, DDM and Starch. Forage blend produced through mixed cropping of corn and soybeans holds a great potential for increasing the forage and nutrient yields to meet the nutrient requirements of lactating dairy cows.

Key words: corn, soybean, organic forage, row cropping

INTRODUCTION

Two noteworthy progresses are currently taking place in the area of forage production. One is the continuous sky rocking price of feedstuffs is forcing many dairy producers to reduce production costs, with the situation becoming so risky that some have even suggested a slaughter program in order to stabilize the current market situation. All at once, an increasing number of farmers are switching to organic dairy production in order to benefit from higher prices per product unit as demand for organic food remains high. The second is an increase in organic dairy farming as a major trend, with demand for food produced according to organic guidelines remaining high in most of the nations. Parsons et al. (2009) reported that organic producers in Vermont spent nearly $1200 per cow per year on purchased feed and 92% of those costs involved purchase concentrates to increase nutrient density of diets in order to boost milk production.

Organic milk production is increasing every year from 1.9 % of total fluid milk production in 2006 to 4.4 % in 2013 (USDA, 2014). One reason for the growth in the organic sector has been the steadily increasing milk price, going from $22.97 in 2004 to $28.84 in 2006 to $29.35 in 2007 to $38.10/cwt in 2016 (CROPP Cooperatives, 2016). However, net profits from organic milk production are headed in the wrong direction as production costs continue to rise. Organic dairy farmers must place an emphasis on quality forages to feed their livestock in order to be successful. Any time of the year, the quality of forage determines what other feeds need to be included for balancing the nutrients in the dairy cow ration. Quality forages provide a nutritional base that maintains digestive function, improves animal health, and supplies nutrients to the dairy cow in a most efficient manner. Quality forages decrease the amount of grains dairy farmers need to purchase to meet their production goals for their dairy cows.

Legumes are useful for assimilating natural nitrogen into crop rotations and forage blends production, which ultimately decrease the cost of fertilizer use. In forage production, forage soybean in particular serve well as a foundation for mixed crops with corn, as shown through preliminary research. Numerous studies have reported that intercropping of soybean with corn resulted an increase in biomass yield by 20 - 40% (Singh et al., 1986) and crude protein by 11-15% (Putnam et al., 1986). The reason for increased silage yield with intercropping compared to monocropping is due to efficient utilization of available sunlight, moisture and nutrients in soil (Etebari and Tansi, 1994).

Silage quality and crude protein concentration increased when soybean planting with corn in alternate rows as 1 corn - 1 soybean or 1 corn - 2 soybean rows compared to sole cropping of corn (Altinok et al., 2005). Smith (2000) reported increased silage yield and crude protein yield while intercropping corn and pole bean together. However, intercropping of corn and soybean together generally produced less DM yield, but high quality silage (increased CP). Practicing alternate-row sowings and benefiting from climbing types of legumes as a component crop had better performances than same-row sowings and dwarf type legume (Geren et al., 2008). Since Mastergraze corn has a high level of total sugar and NDFD, and vining soybean has indeterminate type growth, we hypothesized that intercropping of mixed seeds of Mastergraze corn with vining soybean in a same row produced more biomass and nutrient yields, as well as, quality silage compared to other combination of corn and soybeans.

OBJECTIVES

The objectives of this study was to compare the row cropping of mixed seeds of corn and soybean with different seeding ratios on biomass yield and nutrient yields and to compare the silage blend nutrition and quality grown under organic condition.

MATERIALS AND METHODS

An organic field at the Dairy Research and Training Facility (DRTF) of South Dakota State University, SD was used to conduct this research in the 2015 crop growing season.

Field preparation

Soil preparation consisted of plowing, disking, leveling and layout. The field was prepared without addition of any chemical fertilizer, herbicides and pesticides. However, liquid manure from dairy farm was spread on the field 15 d before planting. A total of 48 plots having equal areas of 29.2 m^2 (5.4 m × 5.4 m) with 8 rows on each were prepared to test the treatments.

Corn and soybean varieties

MC5300 (OC) organic forage corn (103 d maturity) is well known for strong emergence and seeding vigor for organic production and reduced tillage operation, has very good tonnage and bushels per acre with excellent nutrition. It has wide leaf, showy robust plant, excellent dual purpose white cob variety for livestock feed that drives performance (Masters Choice Seed Corn, Anna, IL).

BMR grazing corn (Masters Choice Mastergraze, MG) is a conventional organic corn hybrid famous for best quality BMR forage. It has ability to be grazed and harvested during summer, fall and winter and potential to produce DM up to 12.21 T/ha in 7-8 weeks with ideal growing conditions. Mastergraze BMR qualities include 20-30% higher digestibility, 15-20% protein potential, low lignin, sweet and palatable due to high sugar contents (Masters Choice Seed Corn, Anna, IL).

Viking 2265 organic soybean (OS) is medium-tall, bushy plant type with very good lodging resistance, has excellent emergence and very strong phytophthora field tolerance, has excellent white mold tolerance. It is an excellent cover crop, livestock feed, or smother crop which also used as a trap crop for deer. Biomass and grain yield is comparable to every conventional, roundup ready and large lad soybean (Johnny's selected seeds, Winslow, ME).

Vining soybean line (VS) was developed by soybean breeder at South Dakota State University through intensive selection process from wild soybeans. Growth is indeterminate types and climb to corn if planted together. Preliminary research showed very good potential forage soybean to increase CP content of silage (Plant Science Department, South Dakota State University).

Experimental design and treatments

A field plot study was laid out using a completely randomized design (RCBD) to evaluate two corn hybrids [MC5300 normal organic corn (OC) and BMR grazing corn (Masters Choice Mastergraze, MG)] with two soybean cultivars [Viking 2265 organic (OS) and Vining line (VS)] at four seeding rates (R1 = 65:35; R2 = 55:45; R3 = 45:55, and R4 = 35:65 of corn and soybean respectively) having a 2 x 2 x 4 factorial treatment design replicated three times.

The outline of total treatments was as follows:

Treatment 1 (65% MC 5300 corn + 35% Viking 2265 soybean)

Treatment 2 (55% MC 5300 corn + 45% Viking 2265 soybean)

Treatment 3 (45% MC 5300 corn + 55% Viking 2265 soybean)

Treatment 4 (35% MC 5300 corn + 65% Viking 2265 soybean)

Treatment 5 (65% MC 5300 corn + 35% Vining soybean)

Treatment 6 (55% MC 5300 corn + 45% Vining soybean)

Treatment 7 (45% MC 5300 corn + 55% Vining soybean)

Treatment 8 (35% MC 5300 corn + 65% Vining soybean)

Treatment 9 (65% Mastergraze Corn + 35% Viking 2265soybean)

Treatment 10 (55% Mastergraze Corn + 45% Viking 2265soybean)

Treatment 11 (45% Mastergraze Corn + 55% Viking 2265soybean)

Treatment 12 (35% Mastergraze Corn + 65% Viking 2265soybean)

Treatment 13 (65% Mastergraze Corn + 35% Vining soybean)

Treatment 14 (55% Mastergraze Corn + 45% Vining soybean)

Treatment 15 (45% Mastergraze Corn + 55% Vining soybean)

Treatment 16 (35% Mastergraze Corn + 65% Vining soybean)

Total seeds requirement for each experimental plot were calculated based on corn at 86,487 seeds/ ha and soybean at 3,58,302 seeds/ha. Mixed seeds of corn and soybean were planted by using a 4 row cone plot planter (Almaco, 1986 model KK4RPPSEM) having row spacing of 76.2 cm.

Weeding, harvesting, ensiling, and sampling

Weeds were removed 3 times during the cropping season at 25 and 50 d by using small rotary tiller and manually at 75 d after planting. No irrigation was provided throughout the study period. BMR grazing corn (MG) combining with both soybeans were hand harvested at 101 d after planting whereas MC 5300 corn (OC) combining with both soybeans were hand harvested at 116 d after planting because of differences in maturity d among corn hybrids. Central 2 rows of each experimental plot were harvested to measure fresh biomass yield. Plants were chopped with the help of local shredder, inoculated with Silo-King® plus at recommended dose, packed into buckets, weighed, and ensiled for 90 d. Buckets were then re-weighed, opened, and forage samples collected and submitted for nutrient analysis (Analab, Inc., Fulton, IL).

Sample analyses

Fresh (0) and 90 d ensiled forage samples were analyzed for DM, CP,SP, ADF, NDF,ADIP, NDIP, starch, NFC, NE_L, 6-C Sugar, EE, nitrates, IVDMD, NDFD30, lignin, ash, NH_3-N, pH, lactic acid, acetic acid, butyric acid, Na, Mg, P, S, K, Ca, Cl, Mn, Fe, Cu and Zn (Analab, Inc., Fulton, IL). The AOAC (2006) was used to analyze DM (935.29), CP (990.03), SP (Krishnamoorthy et al., 1982), ADF (973.18), NDF (2002.04), ADIP (Goering and Van Soest, 1970; Goering et al., 1972), NDIP (2002.04 minus sulfite and 976.06), starch (996.11, enzymatic method analyzed on RFA using Glucose Trinder), NFC (100- NDF – CP – Fat – EE), NE_L (NRC,2001), 6-C sugar (Ethanol extract, HPLC with ELSD), EE (920.39), Nitrates (968.07), IVDMD (ANKOM technology - 08/05), NDFD30 (ANKOM technology method 3), lignin (973.18), ash (942.05), NH_3-N

(University of Wisconsin Extension SKU:A3769, MAP 4.3 adapted from USEPA 351.2 and ISO 11732), pH (981.12), lactic acid (LC-GC Vol. 11 No. 10), acetic acid (LC-GC Vol. 11 No. 10), butyric acid (LC-GC Vol. 11 No. 10) and minerals (Ca, P, Mg, K, Na: 985.01; S: 923.01; Cl: 915.01; Mn, Fe, Cu, ZN:985.01).

Estimation of total nitrogen accumulated by the crop

Total nitrogen accumulated by the crops (T/ha) can be calculated as follows:

$$\text{Total N} = \Sigma\,(\text{DMY} \times \text{N \%})$$

Where DMY is the yield of DM (T/ha) and N is the concentration of nitrogen in plant. Crude protein content of forage was used to calculate total nitrogen content. Once DMY per ha was multiplied by nitrogen percentage, we can get total nitrogen uptake by treatment forage on per ha basis.

Net return

$$\text{Net return (\$/ha)} = GI - (S + Mc + L + C + R + CI + Mi + I)$$

Where GI is gross income ($/ha), S is seed costs ($/ha), Mc is machinery expenses ($/ha), L is labor cost ($/ha), C is compost/manure cost ($/ha), and, R is rental land cost ($/ha), CI is crop insurance cost ($/ha), Mi is miscellaneous cost ($/ha), and I is interest on variable cost ($/ha).

Current price of grain and silage published on USDA livestock, poultry and grain market news as of 6th January, 2016 was used to estimate gross income from grain or silage. The prices of organic corn silage (35% DM) and organic soybean silage (35% DM were $95.98, and $141.23 per ton, respectively. Proportion of corn and soybean on forage blends were estimated based on seeding ratios while planting. Gross income from forage blend was estimated based on 35% DM yield of corn and soybean forage multiply by respective market prices. Total cost of forage or grain production was calculated by using cost estimates formula for Iowa State developed by Plastina (2016). Total cost of forage production ($1,743.99/ha) includes seed cost ($320.84/ha), machinery cost ($345.95/ha), labor cost $172.97/ha), compost cost ($160.62/ha), rental land cost ($ 657.30/ha), crop insurance ($30.15/ha), miscellaneous ($24.71/ha), and interest on variable cost ($31.46/ha).

Statistical analysis

Statistical analysis of all data were performed by using the PROC MIXED procedure of SAS subjected to least squares ANOVA (SAS Institute Inc., Cary, NC, Version 9.4) for a randomized complete block design (Steel and Torrie, 1980). Data were tested for heterogeneity of variances and statistical significance was declared at $P \leq 0.05$.

Statistical model used for this experiment was as follows:

$$Y_{ijk} = \mu + C_i + S_j + R_k + (C \times S)_{ij} + (C \times R)_{ik} + (S \times R)_{jk} + (C \times S \times R)_{ijk} + e_{ijk}$$

Where,

Y_{ijk} is the dependent variable

μ is the overall mean,

C_i is the i^{th} main effect of corn (i = 1,2)

S_j is the j^{th} main effect of corn (j = 1,2)

R_k is the k^{th} main effect of seeding ratio (k = 1,2,3,4)

$(C \times S)_{ij}$ is the interaction of corn and soybean

$(C \times R)_{ik}$ is the interaction of corn and seeding ratio

$(S \times R)_{jk}$ is the interaction of soybean and seeding ratio

$(C \times S \times R)_{ijk}$ is the interaction of corn, soybean and seeding ratio (treatment)

e_{ijk} = error term

RESULTS AND DISCUSSION

Temperature and rainfall patterns of crop growing season

The 2015 growing season was normal in terms of temperature and rainfall (Table 7.1) compared to the average temperature and precipitation for past 30 years. Thus, the 2015 crop year can be considered as very good crop year in terms of biomass production of corn and soybean.

Forage biomass and dry matter yield

No interaction of corn × soybean × seeding ratio was detected for biomass yield and nutrient yields. The main effects of corn and soybean, combination of corn and soybean and different seed ratios of corn and soybean on fresh biomass and DM yield are presented in Table 7.2. The main effect of corn for fresh biomass yield (T/ha) was greater ($P < 0.05$) for OC (81.71) compared to MG (71.18). The main effect of soybean for fresh biomass yield (T/ha) was tended to be greater ($P < 0.10$) for VS (78.84) compared to OS (74.04). The combination of OC-VS produced the greatest ($P < 0.05$) fresh biomass yield compared to other combination (77.64, 85.78, 70.44, and 71.91 T/ha for OC-OS, OC-VS, MG-OC, and MG-VS combination of corn and soybean respectively). Corn and soybean seed ratio of R1 produced greater ($P < 0.05$) fresh biomass yield compared to R3 with R2 and R4 being intermediate (82.91, 75.45, 72.11, and 75.29 T/ha for R1, R2, R3, and R4 respectively). Main effect of corn on DM yield (T/ha) was greater ($P < 0.05$) for OC (27.73) compared to MG (19.90), but main effect of soybean on DM yield (T/ha) was similar ($P > 0.05$) for both OC and VS (23.86). The combination of OC-OS and OC-VS produced greater ($P < 0.05$) DM yields compared to MG-OS, and MG-VS (27.24, 28.23, 20.31, and 19.49 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seed ratio of R1and R2 produced more ($P < 0.05$) DM yield compared to R3 and R4 (25.38, 24.48, 21.81, and 23.59 T/ha for R1, R2, R3, and R4 respectively).

Dry matter loss during ensiling process

The main effects of corn and soybean, combination of corn and soybean and different seed ratios of corn and soybean on DM loss are presented in Table 7.2. Main effect of corn on DM loss (T/ha) was greater ($P < 0.05$) for OC compared (0.54) to MG (0.34), but the main effect of soybean on DM loss (T/ha) was similar ($P > 0.05$) for both

OS and VS (0.44).The combination of OC-OS and OC-VS lost greater (P < 0.05) DM compared to MG-OS, and MG-VS (0.52, 0.56, 0.33, and 0.34 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Different corn and soybean seed ratios were similar (P > 0.05) in terms of DM loss (0.44 T/ha).

Nutrient yields of forage

The main effects of corn and soybean, combination of corn and soybean and different seed ratios of corn and soybean on different nutrient yields are presented in Table 7.2 and Figure 7.1. The main effect of corn on digestible dry matter (DDM) yield (T/ha) was higher ($P < 0.05$) for OC (19.55) compared to MG (13.67). However, the main effect of soybean on DDM yield was similar ($P > 0.05$) for both OS and VS (16.61 T/ha). The combination of OC-OS, and OC-VS produced greater ($P < 0.05$) DDM yield compared to MG-OS, and MG-VS (19.29, 19.82, 14.02, and 13.32 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seed ratio of R1 and R2 produced greater ($P < 0.05$) fresh biomass yield compared to R4 with R3 being intermediate (17.70, 17.08, 15.13, and 16.54 T/ha for R1, R2, R3, and R4 respectively). The main effect of corn on CP yield (T/ha) was greater for OC (2.40) compared to MG (2.12), but the main effect of soybean on CP yield was similar for both OS and VS (2.26 T/ha). The combination of OC-OS, and OC-Vs produced greater ($P < 0.05$) CP yield compared to MG-OS, and MG-VS combination (2.39, 2.40, 2.28, and 1.97 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 and R4 tended to produce higher ($P < 0.10$) CP yield compared to R2 and R3 (2.32, 2.31, 2.04, and 2.37 T/ha for R1, R2, R3, and R4 respectively). The main effect of corn on

NDF yield (T/ha) was greater for OC (11.48) compared to MG (10.03), but the main effect of soybean on NDF yield was similar for both OS and VS (10.76 T/ha). The combination of OC-VS produced greater NDF yield compared to MG-OS, and MG-VS with OC-OS being intermediate (11.05, 11.91, 10.11, and 9.94 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 tended to be produce higher ($P < 0.10$) CP yield compared to R3 with R2 and R4 being intermediate (11.33, 10.99, 10.04, and 10.65 T/ha for R1, R2, R3, and R4 respectively). The main effect of corn on OC and MG and soybean on OS and VS for DNDF yield were similar (5.18 T/ha for OC and MG, and 5.18 T/ha for OS, and VS respectively). All combination of corn and soybean produced similar DNDF yield (5.18 T/ha). All corn and soybean seeding ratios produced similar ($P > 0.10$) DNDF yield (5.18 T/ha). The main effect of corn on NFC yield (T/ha) was greater ($P < 0.05$) for OC (12.27) compared to MG (6.52) but the main effect of soybean on NFC yield was similar for both OS and VS (9.40 T/ha). The combination of OC-OS, and OS-VS produced greater ($P < 0.05$) NFC yield compared to MG-OS, and MG-VS (12.18, 12.35, 6.64, and 6.40 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 produce higher ($P < 0.05$) NFC yield compared to R3 and R4 with R2 being intermediate (10.22, 9.74, 8.44, and 9.17 T/ha for R1, R2, R3, and R4 respectively). Main effect of corn on starch yield (T/ha) was greater (P < 0.05) for OC (7.78) compared to MG (2.45), but main effect of soybean on starch yield (T/ha) was similar (P > 0.05) for both OS and VS (5.12). The combination of OC-OS and OC-VS produced greater (P < 0.05) starch yield compared to MG-OS, and MG-VS (7.91, 7.64, 2.59, and 2.31 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratios of R1and R2 produced more ($P < 0.05$) starch yield compared to R3 and R4 (5.81, 5.34, 4.39, and 4.92 T/ha for R1, R2, R3, and R4 respectively). Main effect of corn on NE_L yield (Mcal/ha) was greater ($P < 0.05$) for OC (45553) compared to MG (29675) but main effect of soybean on NE_L yield (Mcal/ha) was similar ($P > 0.05$) for both OS and VS (37614). The combination of OC-OS and OC-VS produced greater ($P < 0.05$) NE_L yield compared to MG-OS, and MG-VS (45143, 45963, 30481, and 28870 Mcal/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratios of R1and R2 produced more ($P < 0.05$) NE_L yield compared to R3 with R4 being intermediate (40187, 38737, 34128, and 37704 Mcal/ha for R1, R2, R3, and R4 respectively).

Milk yields, net return, and nitrogen accumulation by crop

Milk yields, net return from forage, and total nitrogen accumulated by treatment forage are presented in Table 7.3. Main effect of corn on milk yields (T/ha) was greater ($P < 0.05$) for OC (40.99) compared to MG (23.35) but main effect of soybean on milk yields (T/ha) was similar ($P > 0.05$) for both OS and VS (32.17). The combination of OC-OS and OC-VS produced greater ($P < 0.05$) milk yield compared to MG-OS, and MG-VS (41.42, 40.56, 24.81, and 21.89 T/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R3 produced lower ($P < 0.05$) milk yield compared to rest of the seeding ratios (34.75, 33.18, 28.42, and 32.32 T/ha for R1, R2, R3, and R4 respectively). Main effect of corn on net return from forage ($/ha) was greater ($P < 0.05$) for OC (7646.26) compared to MG (4981.82) but main effect of soybean on net return ($/ha) was similar ($P > 0.05$) for both OS and VS (6314.07). The combination of OC-OS and OC-VS provided greater ($P < 0.05$) net return compared to

MG-OS, and MG-VS (7468.62, 7823.91, 5123.30, and 4840.35 net return $/ha for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R4 tended to be greater ($P < 0.10$) net return compared to R3 with R1 and R2 being intermediate and similar (6363.06, 6394.86, 5789.19, and 6709.07 net return $/ha for R1, R2, R3, and R4 respectively). Main effect of corn and soybean on N accumulation (T/ha) was similar ($P > 0.05$) for both OC, and MG corn (0.36), and similar ($P > 0.05$) for both OS and VS soybean (0.36). Total N accumulated by treatment forage was similar ($P > 0.05$) for all corn and soybean combinations (0.36 T/ha). Total nitrogen accumulated by treatment forage was greater ($P < 0.05$) for corn and soybean seeding ratio of R4 compared to T1 with T2 and T3 being intermediate and similar (0.32, 0.36, 0.34, and 0.40 T/ha for R1, R2, R3, and R4 respectively).

Nutrient composition of forage

The main effects of corn and soybean, combination of corn and soybean and different seeding ratios of corn and soybean on nutrient composition of forage is presented in Table 7.4. The main effect of corn on DM percentage was greater ($P < 0.05$) for OC (32.43%) compared to MG (25.82), but the main effect of soybean on DM percentage was similar ($P > 0.05$) for OS and VS (29.13%). The combination of OC-OS and OC-VS produced greater ($P < 0.05$) DM percentage compared to MG-OS and MG-VS (32.90, 31.97, 26.17, and 25.46% DM for OC-OS, OC-VS, MG-OS, and MG-VS respectively). All corn and soybean seeding ratios produced forage being similar ($P > 0.05$) DM % (29.13). The main effect of corn on CP concentration was greater ($P < 0.05$) for MG (10.58) compared to OC (8.59) and the main effect of soybean on CP concentration was greater (*P* < 0.05) for OS (9.95) compared to VS (9.22). The combination of MG-OS produced greater (*P* < 0.05) CP concentration compared to OC-VS with OC-OS and MG-VS being intermediate (8.70, 8.48, 11.20, and 9.97% CP for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R4 produced forage having greater (*P* < 0.05) CP concentration compared to R1 and R3 with R2 being intermediate (9.24, 9.57, 9.33, and 10.20% CP for R1, R2, R3, and R4 respectively). The main effect of corn on SP concentration was greater (*P* < 0.05) for MG (51.10) compared to OC (46.81) and the main effect of soybean on CP% was similar (*P* > 0.05) for OS and VS (48.95). The combination of MG-OS and MG-VS produced greater (*P* < 0.05) SP concentration compared to OC-OS and OC-VS (15.91, 47.70, 51.65, and 50.55 for OC-OS, OC-VS, MG-OS, and MG-VS respectively). All corn and soybean seeding ratios produced forage having similar (*P* > 0.05) SP concentration (48.96, 49.31, 48.12, and 49.42% SP for R1, R2, R3, and R4 respectively). The main effect of corn on NDF concentration was greater (*P* < 0.05) for MG (50.41) compared to OC (41.34) and the main effect of soybean on NDF concentration was higher (*P* < 0.05) for VS (46.57) compared to OS (45.19). The combination of MG-OS and MG-VS produced forage having greater (*P* < 0.05) NDF concentration compared to OC-OS and OC-VS (40.56, 42.13, 49.81, and 51.01% NDF for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R3 tended to be produce greater (*P* < 0.10) NDF concentration compared to R1 with R2 and R4 being intermediate (45.23, 45.71, 46.66, and 45.91% NDF for R1, R2, R3, and R4 respectively). The main effect of corn on DNDF concentration was greater (*P* < 0.05) for MG (26.45) compared to OC (18.37) and the main effect of soybean on DNDF concentration was higher (*P* < 0.05) for VS (22.68) compared to OS (22.14). The combination of MG-OS and MG-VS produced forage having greater (*P* < 0.05) DNDF concentration compared to OC-OS and OC-VS (17.99, 18.74, 26.29, and 26.62% DNDF for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R4 produced greater (*P* < 0.05) DNDF concentration compared to R1 and R2 with R3 being intermediate (21.56, 22.22, 22.83, and 23.02% DNDF for R1, R2, R3, and R4 respectively). The main effect of corn on hemicellulose concentration was greater (*P* < 0.05) for MG (20.87) compared to OC (17.69) and the main effect of soybean on hemicellulose concentration was tended to be higher (*P* < 0.10) for VS (19.45) compared to OS (19.11). The combination of MG-OS and MG-VS produced forage having greater (*P* < 0.05) hemicellulose concentration compared to OC-OS and OC-VS (17.42, 17.96, 20.7, and 20.95% hemicellulose for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R4 produced greater (*P* < 0.05) hemicellulose concentration compared to R1 with R2 and R3 being intermediate (18.93, 19.31, 19.23, and 19.65% hemicellulose for R1, R2, R3, and R4 respectively). The main effect of corn on cellulose concentration was greater (*P* < 0.05) for MG (26.82) compared to OC (21.15) and the main effect of soybean on cellulose concentration was higher (*P* < 0.05) for VS (24.41) compared to OS (23.56). The combination of MG-OS and MG-VS produced forage having greater (*P* < 0.05) cellulose concentration compared to OC-OS, and OC-VS (20.70, 21.61, 26.43, and 27.21% cellulose for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R3 produced greater (*P* < 0.05) cellulose concentration compared to R1, R2 and R4 (21.94, 20.54, 18.68, and 1954% cellulose for R1, R2, R3, and R4 respectively). The main effect of corn on starch concentration was greater (*P* <

0.05) for OC (28.16) compared to MG (12.19) and the main effect of soybean on starch concentration was higher ($P < 0.05$) for OS (20.94) compared to VS (19.41). The combination of OC-OS and OC-VS produced forage having greater ($P < 0.05$) starch concentration compared to MG-OS and MG-VS (29.14, 27.18, 12.74, and 11.64% starch for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 and R2 produced greater ($P < 0.05$) starch concentration compared to R3, and R4 (21.94, 20.54, 18.68, and 19.54% starch for R1, R2, R3, and R4 respectively). The main effect of corn on sugar concentration was greater ($P < 0.05$) for MG (2.88) compared to OC (1.67) and the main effect of soybean on sugar concentration was higher ($P < 0.05$) for VS (2.49) compared to OS (2.06). The combination of MG-OS and MG-VS produced forage having greater ($P < 0.05$) sugar concentration compared to OC-OS, and OC-VS (1.48, 1.85, 2.63, and 3.13% sugar for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R3 produced greater ($P < 0.05$) sugar concentration compared to R1 with R2 and R4 being intermediate (1.90, 2.18, 2.63, and 2.39% sugar for R1, R2, R3, and R4 respectively). The main effect of corn on NFC concentration was greater ($P < 0.05$) for OC (44.36) compared to MG (32.79) and the main effect of soybean on NFC concentration was similar ($P > 0.05$) for OS and VS (38.57). The combination of OC-OS, and OC-VS produced forage having greater NFC concentration compared to MG-OS and MG-VS (44.87, 43.84, 32.62, and 32.96% NFC for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 produced greater ($P < 0.05$) NFC concentration compared to R3 and R4 with R2 being intermediate (39.59, 38.84, 37.96, and 37.91% NFC for R1, R2, R3, and R4 respectively). The main effect of corn on NE_L concentration (Mcal/kg) was greater ($P <$

0.05) for OC (1.65) compared to MG (1.50) and the main effect of soybean on NE_L (Mcal/kg) was greater ($P > 0.05$) for OS (1.59) compared to VS (1.57). The combination of OC-OS produced forage having greater ($P < 0.05$) NE_L compared to MG-OS and MG-VS with OC-VS being intermediate (1.65, 1.63, 1.50, and 1.48 Mcal/kg NE_L for OC-OS, OC-VS, MG-OS, and MG-VS respectively). All corn and soybean seeding ratios produced similar ($P > 0.05$) NE_L (1.56 Mcal/kg). The main effect of corn on fiber digestion (NDFD30) was greater ($P < 0.05$) for MG (52.49%) compared to OC (44.47) and the main effect of soybean on NDFD30 was similar ($P > 0.05$) for OS and VS (48.48%). The combination of MG-OS, and MG-VS produced forage having greater ($P < 0.05$) NDFD30 compared to OC-OS and OC-VS (44.38, 44.55, 52.78, and 52.20% NDFD30 for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R4 produced greater ($P < 0.05$) NDFD30 compared to R1and R2 with R3 being intermediate (47.27, 48.23, 48.53, and 49.87% NDFD30 for R1, R2, R3, and R4 respectively). The main effect of corn on lignin content was greater ($P < 0.05$) for MG (2.72%) compared to OC (2.50%) and the main effect of soybean on NDFD30 was greater ($P < 0.05$) for VS (2.70%) compared to OS (2.52%). The combination of MG-VS produced forage having greater ($P < 0.05$) lignin concentration compared to OC-OS, OC-VS, and MG-OS (2.44, 2.57, 2.59, and 2.85% lignin for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R3 produced greater ($P < 0.05$) lignin concentration compared to R1, R2, and R4 (2.59, 2.59, 2.79, 2.49% lignin for R1, R2, R3, and R4 respectively). The main effect of corn on ash concentration was greater ($P < 0.05$) for MG (5.29%) compared to OC (3.81) and the main effect of soybean on ash content was similar ($P > 0.05$) for OS and VS (4.55%). The combination of MG-OS, and

MG-VS produced forage having greater ($P < 0.05$) ash concentration compared to OC-OS, and OC-VS (3.77, 3.84, 5.21, and 5.37% ash for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R3 produced greater ($P < 0.05$) ash content compared to R2 with R1 and R4 being intermediate (4.48, 4.42, 4.70, and 4.53% ash for R1, R2, R3, and R4 respectively). The main effect of corn on pH value was similar ($P > 0.05$) for OC and MG (4.04) and the main effect of soybean on pH value was similar ($P > 0.05$) for OS and VS (4.05). The combination of MG-OS produced silage having lower ($P < 0.05$) pH value compared to OC-OS, OC-VS, and MG-VS (4.06, 4.07, 3.98, and 4.07 for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 produced silage having greater ($P < 0.05$) pH value compared to R4 with R2, and R3 being intermediate (4.10, 4.04, 4.03, and 3.99 pH for R1, R2, R3, and R4 respectively). The main effect of corn on lactic acid concentration was greater ($P < 0.05$) for MG (6.60%) compared to OC (4.01%) and the main effect of soybean on lactic acid concentration was similar ($P > 0.05$) for OS and VS (5.31%). The combination of MG-OS and MG-VS produced forage having higher ($P < 0.05$) lactic acid concentration compared to OC-OS, and OC-VS (4.02, 3.99, 6.69, 6.50% lactic acid for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R1 produced forage having lower ($P < 0.05$) lactic acid concentration compared to R2, R3, and R4 (4.89, 5.43, 5.33, and 5.33% lactic acid for R1, R2, R3, and R4 respectively).

Mineral composition of forages

The main effects of corn and soybean, combination of corn and soybean and different seed ratios of corn and soybean on mineral composition of forage is presented in

Table 7.5. The main effect of corn on Ca concentration was greater ($P < 0.05$) for MG (0.45%) compared to OC (0.28%) and the main effect of soybean on Ca concentration was greater ($P < 0.05$) for OS (0.40%) compared to VS (0.33%). The combination of MG-OS produced greater ($P < 0.05$) Ca concentration compared to OC-OS, OC-VS, and MG-VS (0.30, 0.27, 0.50, and 0.40% Ca for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seed ratio of R4 produced forage having greater ($P < 0.05$) Ca concentration compared to R1 with R2, and R3 being intermediate (0.33, 0.37, 0.37, and 0.40% Ca for R1, R2, R3, and R4 respectively). The main effect of corn and soybean on P concentration was similar ($P > 0.05$) for both corn (0.23%) and both soybean (0.23%). The combination of different corn and soybean produced similar ($P > 0.05$) P concentration (0.23%). Corn and soybean seed ratio of R4 produced greater ($P < 0.05$) P concentration compared to R2 and R3 with R1 being intermediate (0.23, 0.22, 0.23, and 0.24% P for R1, R2, R3, and R4 respectively). The main effect of corn on Mg concentration was greater ($P < 0.05$) for MG (0.30%) compared to OC (0.20%) and the main effect of soybean on Mg concentration was similar ($P > 0.05$) for OS and VS (0.25%). The combination of MG-OS and MG-VS produced greater ($P < 0.05$) Mg concentration compared to OC-OS, and OC-VS (0.21, 0.20, 0.31, and 0.29% Mg for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Different corn and soybean seeding ratios produced similar ($P > 0.05$) Mg concentration (0.25%).The main effect of corn on K and Na concentration was greater ($P < 0.05$) for MG (1.40% K, and 0.05% Na) compared to OC (1.00% K, and 0.03% Na) and the main effect of soybean on K and Na concentration was similar ($P > 0.05$) for OS and VS (1.20% K, and 0.04% Na). The combination of MG-OS and MG-VS produced greater ($P < 0.05$) K concentration

compared to OC-OS, and OC-VS (0.95, 1.06, 1.41, and 1.39% K for OC-OS, OC-VS, MG-OS, and MG-VS respectively). The combination of MG-OS and MG-VS produced greater ($P < 0.05$) Na concentration compared to OC-OS, and OC-VS (0.03, 0.03, 0.05, and 0.06% Na for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Different corn and soybean seeding ratios produced forage having similar ($P > 0.05$) K and Na concentration (1.20% K and 0.04% Na). The main effect of corn and soybean on Cl concentration was similar ($P > 0.05$) for corn (0.42%) and soybean (0.43%). The combination of MG-OS produced greater ($P < 0.05$) Cl concentration compared to OC-OS with OC-VS with MG-VS being intermediate (0.38, 0.43, 0.46, and 0.43% Cl for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Different corn and soybean seeding ratios produced forage having similar ($P > 0.05$) Cl concentration (0.43%). The main effect of corn on forage S concentration was greater ($P < 0.05$) for MG (0.12%) compared to OC (0.07%) and the main effect of soybean on forage S concentration was greater ($P < 0.05$) for OS (0.10%) compared to VS (0.42%). The combination of MG-OS produced greater ($P < 0.05$) S concentration compared to OC-OS and OC-VS with MG-VS being intermediate (0.07, 0.06, 0.13, and 0.11% S for OC-OS, OC-VS, MG-OS, and MG-VS respectively). Corn and soybean seeding ratio of R4 produced greater ($P < 0.05$) forage S concentration compared to R1 with R2, and R3 being intermediate (0.09, 0.09, 0.09, and 0.10% S for R1, R2, R3, and R4 respectively). The main effect of corn on forage Mn, Fe, Cu, Zn, and Al concentration were greater ($P < 0.05$) for MG (36.10, 289.99, 6.44, 58.93, and 159.00 ppm for Mn, Fe, Cu, Zn, and Al respectively) compared to OC (26.01, 117.56, 3.93, 26.47, and 33.00 ppm for Mn, Fe, Cu, Zn, and Al respectively). The main effect of soybean on forage Mn, Fe, Cu, Zn, and Al concentration was similar (*P* > 0.05) for OS and VS (31.06, 203.77, 5.19, 42.71, and 96.00 ppm for Mn, Fe, Cu, Zn, and Al respectively). The combination of MG-OS, and MG-VS produced greater (*P* < 0.05) forage Mn, Fe, Cu, Zn, Al concentration compared to OC-OS and OC-VS. Corn and soybean seeding ratio of R4 produced greater (*P* < 0.05) forage Mn concentration compared to R1 with R2, and R3 being intermediate (28.39, 30.53, 32.28, and 33.03 ppm for R1, R2, R3, and R4 respectively). All corn and soybean seeding ratios produced similar (*P* < 0.05) forage Fe, Zn, and Al concentration (203.77, 42.70, and 96.00 ppm for Fe, Zn, and Al respectively). Corn and soybean seeding ratio of R2 produced greater (*P* < 0.05) forage Cu concentration compared to R1 and R3 with R4 being intermediate (4.94, 5.78, 4.97, and 5.06 ppm for R1, R2, R3, and R4 respectively).

CONCLUSIONS

No interaction of corn × soybean × seeding ratio was detected for biomass yields and nutrient yields. The main effect of corn on fresh, DM, DDM, CP, NDF, NFC and starch yield was greater for Masters Choice 5300 corn compared to BMR grazing corn. The main effect of soybean on Viking 2265 and Vining soybean was similar on DM, DDM, CP, NDF, NFC and starch yield. Masters Choice 5300 corn with either soybeans produced higher fresh, DM and nutrient yields. Corn and soybean seeding ratio at 65:35 produced more forage and nutrient yields compared to other combination and seeding ratios. Masters Choice 5300 corn was superior over BMR grazing corn (Masters Choice Mastergraze) for biomass production and nutrient yields. Viking 2265 and Vining soybeans were similar in biomass production and nutrient yields. However, BMR grazing corn and Viking 2265 soybean were richer in most of the mineral contents compared to Masters Choice 5300 corn and Vining soybean.

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Table 7.1. Climatic conditions during the 2015 growing season[1]

	Temperature, °C		Precipitation, mm	
Months	Mean	Deviation[2]	Total	Deviation[2]
April	8.3	1.9	7.6	-49.6
May	12.8	-0.7	119.1	10.8
June	19.4	0.5	58.4	-52.7
July	21.7	0.4	100.6	20.3
August	19.4	-0.5	176.8	101.6
September	18.3	3.2	43.7	-35.4
October	10.0	2.4	29.5	-15.7
November	3.3	4.3	33.5	15.2

[1] Data collected from a weather station located at South Dakota State University approximately 3 km from the plots.

[2] Deviation = actual minus 30 year monthly average.

Table 7.2. Forage and nutrient yields (T/ha unless noted) when row cropping of mixed seeds of corn and soybean with different seeding ratios grown under organic condition

	Main effects[1]														
	Corn		Soybean			Corn and soybean combinations[2]					Seeding ratios[3]				
Yield	OC	MG	OS	VS	SEM	OC*OS	OC*VS	MG*OS	MG*VS	SEM	R1	R2	R3	R4	SEM
Fresh biomass	81.71^{a}	71.18^{b}	74.04^{f}	78.84^{e}	6.46	77.64^{b}	85.78^{a}	70.44^{b}	71.91^{b}	6.75	82.91^{a}	75.45^{ab}	72.11^{b}	75.29^{ab}	6.75
DM[4]	27.73^{a}	19.90^{b}	23.77	23.86	1.78	27.24^{a}	28.23^{a}	20.31^{b}	19.49^{b}	1.90	25.38^{a}	24.48^{a}	21.81^{b}	23.59^{b}	1.90
DM loss	0.54^{a}	0.34^{b}	0.43	0.45	0.04	0.52^{a}	0.56^{a}	0.33^{b}	0.34^{b}	0.05	0.48	0.43	0.47	0.38	0.05
DMD[5]	19.55^{a}	13.67^{b}	16.65	16.57	1.26	19.29^{a}	19.82^{a}	14.02^{b}	13.32^{b}	1.34	17.70^{a}	17.08^{a}	15.13^{b}	16.54^{ab}	1.34
CP[6]	2.40^{a}	2.12^{b}	2.33	2.19	0.21	2.39^{a}	2.40^{a}	2.28^{ab}	1.97^{b}	0.22	2.32^{e}	2.31^{ef}	2.04^{f}	2.37^{e}	0.22
NDF[7]	11.48^{a}	10.03^{b}	10.58	10.93	0.80	11.05^{ab}	11.91^{a}	10.11^{b}	9.94^{b}	0.87	11.33^{e}	10.99^{ef}	10.04^{f}	10.65^{ef}	0.87
DNDF[8]	5.10	5.25	5.12	5.23	0.41	4.91	5.29	5.33	5.17	0.44	5.34	5.28	4.84	5.25	0.44
NFC[9]	12.27^{a}	6.52^{b}	9.41	9.38	0.69	12.18^{a}	12.35^{a}	6.64^{b}	6.40^{b}	0.73	10.22^{a}	9.74^{ab}	8.44^{c}	9.17^{bc}	0.73
Starch	7.78^{a}	2.45^{b}	5.25	4.98	0.35	7.91^{a}	7.64^{a}	2.59^{b}	2.31^{b}	0.39	5.81^{a}	5.34^{a}	4.39^{b}	4.92^{b}	0.39
NE$_L$[10] yield, Mcal/ha	45553^{a}	29675^{b}	37812	37416	2871	45143^{a}	45963^{a}	30481^{b}	28870^{b}	3046	40187^{a}	38737^{a}	34128^{b}	37404^{ab}	3046

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)
[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)
[1] OC = MC 5300 corn, MG = Mastergraze corn, OS = Viking 2265 soybean, VS = Vining soybean
[2] OC*OS = combination of MC 5300 corn + Viking 2265 soybean, OC*VS = combination of MC 5300 corn + Vining soybean, MG*OS = combination of Mastergraze corn + Viking 2265 soybean, MG*VS = combination of Mastergraze corn + Vining soybean
[3] R1 = 65:35; R2 = 55:45; R3 = 45:55, R4 = 35:65 of corn and soybean seeding ratios
[4] Dry matter; [5] Digestible dry matter; [6] Crdue protein; [7] Neutral detergent fiber; [8] Digestible neutral detergent fiber; [9] Non fiber carbohydrate; [10] Estimated net energy for lactation through NRC (2001)

Table 7.3. Milk yield, net return, and nitrogen accumulation by treatment forage when row cropping of mixed seeds of corn and soybean with different seeding ratios grown under organic condition

	Main effects[1]														
	Corn		Soybean			Corn and soybean combinations[2]					Seeding ratios[3]				
Item	OC	MG	OS	VS	SEM	OC*OS	OC*VS	MG*OS	MG*VS	SEM	R1	R2	R3	R4	SEM
Milk[4], T/ha	40.99^{a}	23.35^{b}	33.11	31.22	2.36	41.42^{a}	40.56^{a}	24.81^{b}	21.89^{b}	2.54	34.75^{a}	33.18^{a}	28.42^{b}	32.32^{a}	2.54
Net return[5], $/ha	7646.26^{a}	4981.82^{b}	6296.00	6332.13	595.26	7468.62^{a}	7823.91^{a}	5123.30^{b}	4840.35^{b}	637.12	6363.06^{ef}	6394.86^{ef}	5789.19^{f}	6709.07^{e}	713.51
N accumulation[6], T/ha	0.34	0.37	0.36	0.35	0.03	0.33	0.35	0.39	0.35	0.03	0.32^{b}	0.36^{ab}	0.34^{ab}	0.4^{a}	0.03

[a,b] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] OC = MC 5300 corn, MG = Mastergraze corn, OS = Viking 2265 soybean, VS = Vining soybean

[2] OC*OS = combination of MC 5300 corn + Viking 2265 soybean, OC*VS = combination of MC 5300 corn + Vining soybean, MG*OS = combination of Mastergraze corn + Viking 2265 soybean, MG*VS = combination of Mastergraze corn + Vining soybean

[3] R1 = 65:35; R2 = 55:45; R3 = 45:55, R4 = 35:65 of corn and soybean seeding ratios

[4] Milk yield potential of forage estimated through MILK2006; [5] Net return from silage blend; [6] Nitrogen accumulation by treatment forage

Table 7.4. Nutrient composition of forage when row cropping of mixed seeds of corn and soybean with different seeding ratios grown under organic condition

	Main effects[1]														
Nutrient composition	Corn		Soybean			Corn*Soybean[2]					Seeding ratios[3]				
	OC	MG	OS	VS	SEM	OC*OS	OC*VS	MG*OS	MG*VS	SEM	R1	R2	R3	R4	SEM
DM, %	32.43^{a}	25.82^{b}	29.54	28.71	1.05	32.90^{a}	31.97^{a}	26.17^{b}	25.46^{b}	1.14	29.17	29.23	28.68	29.42	1.14
……………………………………………………………...% of DM unless noted………………………………………………………………															
CP	8.59^{b}	10.58^{a}	9.95^{a}	9.22^{b}	0.21	8.70^{bc}	8.48^{c}	11.20^{a}	9.97^{b}	0.27	9.24^{b}	9.57^{ab}	9.33^{b}	10.20^{a}	0.27
SP[4], % of CP	46.81^{b}	51.10^{a}	48.78	49.12	0.89	45.91^{b}	47.70^{b}	51.65^{a}	50.55^{a}	1.03	48.96	49.31	48.12	49.42	1.03
ADIP[5]	0.35^{b}	0.60^{a}	0.48	0.47	0.01	0.35^{b}	0.35^{b}	0.61^{a}	0.60^{a}	0.01	0.46	0.47	0.48	0.49	0.01
NDIP[6]	0.83^{b}	1.44^{a}	1.12	1.15	0.05	0.82^{b}	0.84^{b}	1.42^{a}	1.47^{a}	0.06	1.07^{b}	1.09^{b}	1.21^{a}	1.18^{ab}	0.06
ADF	23.66^{b}	29.54^{a}	26.08^{b}	27.12^{a}	0.44	23.14	24.17	29.02	30.06	0.53	26.30	26.40	27.43	26.26	0.53
NDF	41.34^{b}	50.41^{a}	45.19^{b}	46.57^{a}	0.58	40.56^{c}	42.13^{b}	49.81^{a}	51.01^{a}	0.69	45.23^{f}	45.71^{ef}	46.66^{e}	45.91^{ef}	0.69
DNDF[7]	18.37^{b}	26.45^{a}	22.14^{b}	22.68^{a}	0.51	17.99^{c}	18.74^{b}	26.29^{a}	26.62^{a}	0.53	21.56^{c}	22.22^{bc}	22.83^{ab}	23.02^{a}	0.53
Hemicellulose	17.69^{b}	20.87^{a}	19.11^{f}	19.45^{e}	0.16	17.42^{b}	17.96^{b}	20.7^{9a}	20.95^{a}	0.21	18.93^{b}	19.31^{ab}	19.23^{ab}	19.65^{a}	0.21
Cellulose	21.15^{b}	26.82^{a}	23.56^{b}	24.41^{a}	0.42	20.70^{b}	21.61^{b}	26.43^{a}	27.21^{a}	0.48	23.71^{f}	23.82^{f}	24.64^{e}	23.77^{f}	0.48
Starch	28.16^{a}	12.19^{b}	20.94^{a}	19.41^{b}	0.70	29.14^{a}	27.18^{a}	12.74^{b}	11.64^{b}	0.89	21.94^{a}	20.54^{a}	18.68^{b}	19.54^{b}	0.89
Sugar	1.67^{b}	2.88^{a}	2.06^{b}	2.49^{a}	0.14	1.48^{b}	1.85^{b}	2.63^{a}	3.13^{a}	0.20	1.90^{b}	2.18^{ab}	2.63^{a}	2.39^{ab}	0.20

NFC[8]	44.36^{a}	32.79^{b}	38.74	38.40	0.75	44.87^{a}	43.84^{a}	32.62^{b}	32.96^{b}	0.86	39.59^{a}	38.84^{ab}	37.96^{b}	37.91^{b}	0.86
NEL, Mcal/kg	1.65^{a}	1.50	1.59^{a}	1.57	0.02	1.65^{a}	1.63^{ab}	1.50^{b}	1.48^{b}	0.02	1.57	1.57	1.54	1.57	0.02
EE	2.73^{a}	2.36^{b}	2.74^{a}	2.35^{b}	0.06	2.91^{a}	2.55^{b}	2.57^{b}	2.15^{c}	0.08	2.52	2.53	2.51	2.62	0.08
IVDMD[9]	70.55^{a}	68.66^{b}	69.94	69.27	0.31	70.85^{a}	70.26^{ab}	69.03^{bc}	68.29^{c}	0.44	69.62	69.64	69.16	70.00	0.44
NDFD[10]	44.47b	52.49a	48.58	48.38	0.61	44.38^{b}	44.55^{b}	52.78^{a}	52.20^{a}	0.70	47.27^{b}	48.23^{b}	48.53^{ab}	49.87^{a}	0.70
Lignin	2.50^{b}	2.72^{a}	2.52^{b}	2.70^{a}	0.06	2.44^{b}	2.57^{b}	2.59^{b}	2.85^{a}	0.08	2.59^{ab}	2.59^{ab}	2.79^{a}	2.49^{b}	0.08
Ash	3.81^{b}	5.29^{a}	4.49	4.60	0.18	3.77^{b}	3.84^{b}	5.21^{a}	5.37^{a}	0.20	4.48^{ab}	4.42^{b}	4.70^{a}	4.53^{ab}	0.20
PH, scale	4.06	4.02	4.02	4.07	0.02	4.06^{a}	4.07^{a}	3.98^{b}	4.07^{a}	0.03	4.10^{a}	4.04^{ab}	4.03^{ab}	3.99^{b}	0.03
Lactic acid	4.01^{b}	6.60^{a}	5.36	5.25	0.10	4.02^{b}	3.99^{b}	6.69^{a}	6.50^{a}	0.14	4.89^{b}	5.43^{a}	5.33^{a}	5.33^{a}	0.14
Acetic acid	1.37^{a}	0.82^{b}	1.10	1.09	0.19	1.31^{a}	1.43^{a}	0.89^{b}	0.75^{b}	0.20	1.06	1.05	1.16	1.11	0.20

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)

[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)

[1] OC = MC 5300 corn, MG = Mastergraze corn, OS = Viking 2265 soybean, VS = Vining soybean

[2] OC*OS = combination of MC 5300 corn + Viking 2265 soybean, OC*VS = combination of MC 5300 corn + Vining soybean, MG*OS = combination of Mastergraze corn + Viking 2265 soybean, MG*VS = combination of Mastergraze corn + Vining soybean

[3] R1 = 65:35; R2 = 55:45; R3 = 45:55, R4 = 35:65 of corn and soybean seeding ratios

[4] Soluble protein; [5] Acid detergent insoluble protein; [6] Neutral detergent insoluble protein; [7] Digestible neutral detergent fiber; [8] Non fiber carbohydrate; [9] In vitro dry matter digestibility; [10] In vitro neutral detergent fiber digestibility for 30 h

Table 7.5. Mineral composition (% of DM unless noted) of forage when row cropping of mixed seeds of corn and soybean with different seeding ratios grown under organic condition

	Main effects[1]														
Mineral	Corn		Soybean			Corn*Soybean[2]					Seeding ratios[3]				
Composition	OC	MG	OS	VS	SEM	OC*OS	OC*VS	MG*OS	MG*VS	SEM	R1	R2	R3	R4	SEM
Ca	0.28^{b}	0.45^{a}	0.40^{a}	0.33^{b}	0.01	0.30^{c}	0.27^{c}	0.50^{a}	0.40^{b}	0.02	0.33^{b}	0.37^{ab}	0.37^{ab}	0.40^{a}	0.02
P	0.23	0.23	0.23	0.23	0.00	0.22	0.23	0.24	0.23	0.01	0.23^{ab}	0.22^{b}	0.23^{b}	0.24^{a}	0.01
Mg	0.20^{b}	0.30^{a}	0.26	0.24	0.02	0.21^{b}	0.20^{b}	0.31^{a}	0.29^{a}	0.02	0.23	0.26	0.26	0.25	0.02
K	1.00^{b}	1.40^{a}	1.18	1.22	0.13	0.95^{b}	1.06^{b}	1.41^{a}	1.39^{a}	0.13	1.19	1.17	1.17	1.28	0.13
Na	0.03^{b}	0.05^{a}	0.04	0.04	0.00	0.03^{b}	0.03^{b}	0.05^{a}	0.06^{a}	0.00	0.04	0.04	0.04	0.05	0.00
Cl	0.40	0.44	0.42	0.43	0.03	0.38^{b}	0.43^{ab}	0.46^{a}	0.43^{ab}	0.04	0.45	0.43	0.42	0.40	0.04
S	0.07^{b}	0.12^{a}	0.10^{a}	0.09^{b}	0.00	0.07^{c}	0.06^{c}	0.13^{a}	0.11^{b}	0.00	0.09^{b}	0.09^{ab}	0.09^{ab}	0.10^{a}	0.00
Mn, ppm	26.01^{b}	36.10^{a}	31.96	30.15	1.31	26.11^{b}	25.92^{b}	37.81^{a}	34.39^{a}	1.59	28.39^{b}	30.53^{ab}	32.28^{a}	33.03^{a}	1.59
Fe, ppm	117.56^{b}	289.99^{a}	191.51	216.03	21.43	115.17^{b}	119.94^{b}	267.86^{a}	312.11^{a}	26.72	209.58	193.00	197.58	214.92	26.72
Cu, ppm	3.93^{b}	6.44^{a}	5.13	5.25	0.30	3.81^{b}	4.06^{b}	6.44^{a}	6.44^{a}	0.36	4.94^{b}	5.78^{a}	4.97^{b}	5.06^{ab}	0.36
Zn, ppm	26.47^{b}	58.93^{a}	40.49	44.92	4.38	24.89^{b}	28.06^{b}	56.08^{a}	61.78^{a}	4.95	45.83	40.28	38.83	45.86	4.95
Al, ppm	33.00^{b}	159.00^{a}	96.36	95.64	9.94	33.33^{b}	32.67^{b}	159.39^{a}	158.61^{a}	14.06	102.56	95.28	87.11	99.06	14.06

[a,b,c] Least squares means within the same row without a common superscript differ ($P < 0.05$)
[e,f] Least squares means within the same row without a common superscript differ ($P < 0.10$)
[1] OC = MC 5300 corn, MG = Mastergraze corn, OS = Viking 2265 soybean, VS = Vining soybean
[2] OC*OS = combination of MC 5300 corn + Viking 2265 soybean, OC*VS = combination of MC 5300 corn + Vining soybean, MG*OS = combination of Mastergraze corn + Viking 2265 soybean, MG*VS = combination of Mastergraze corn + Vining soybean
[3] R1 = 65:35; R2 = 55:45; R3 = 45:55, R4 = 35:65 of corn and soybean seeding ratios

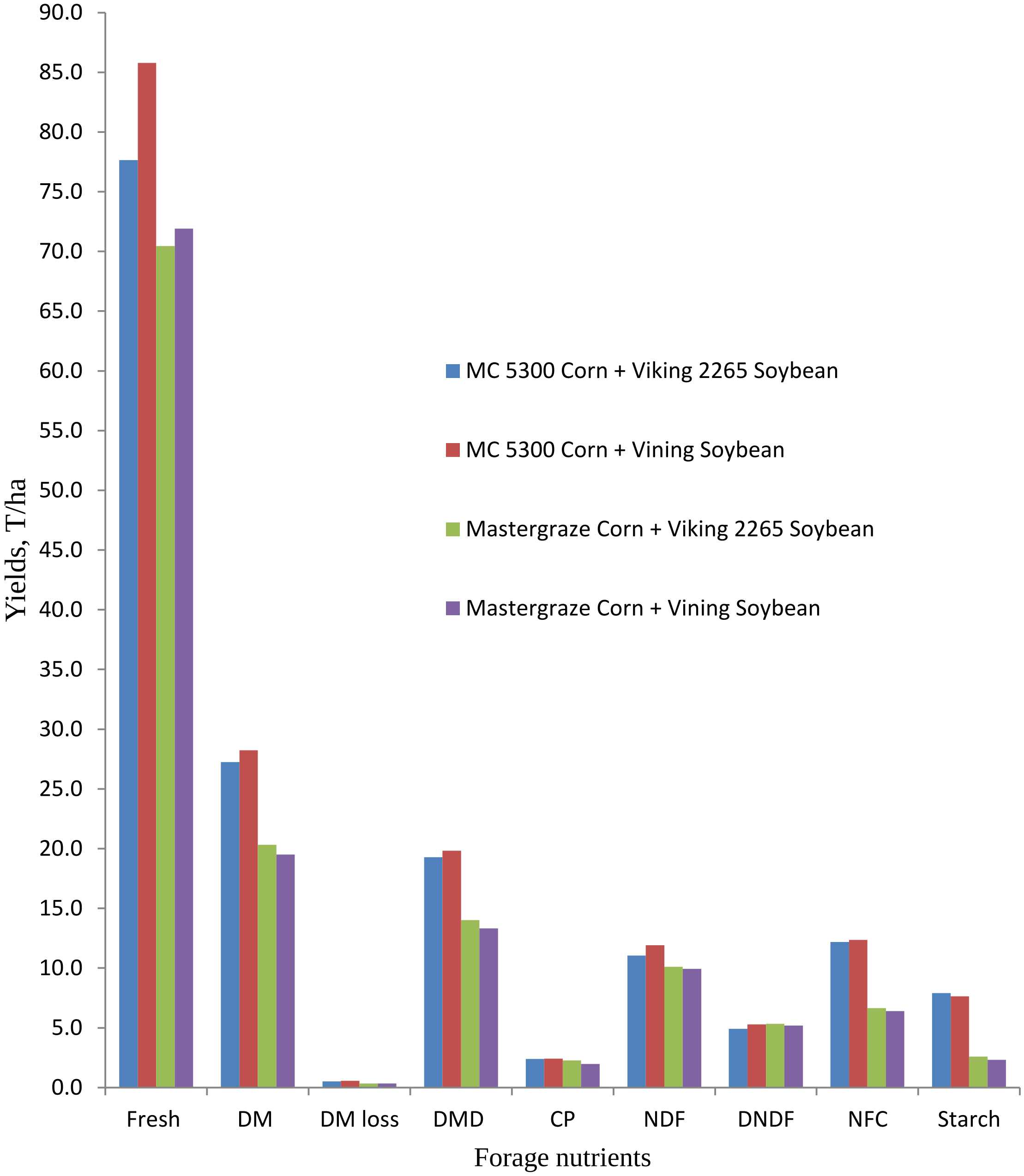

Figure 7.1 Nutrient yields of forage when row cropping of mixed seeds of corn and soybean at different combinations grown under organic condition

OVERALL SUMMARY AND CONCLUSIONS

Importance of water quality, forage quality and forage blends to increased feed efficiency of dairy cows are always underestimated. The first study was conducted to evaluate the effect of water having different qualities on ruminal fermentation, nutrient digestibility and total gas production, which was discussed in chapter 2. The second study was conducted to compare feeding quality of newly developed leafy floury corn silage hybrids with conventional starchy corn silage hybrids on overall animal performance and ruminal characteristics, which was discussed in chapter 3. Study 3, 4, 5 and 6 were conducted to produce forage blends of corn and soybean having higher biomass yield with greater nutrient composition, which were discussed in chapter 4, 5, 6, and 7. Thus, the aim of overall 6 studies were to increase the feed efficiency in lactating dairy cows through production of corn-soybean forage blends, improved water quality and forage quality.

The first study demonstrated that the source and nutrient content of water can affect rate of ruminal fermentation and gas production. The use of laboratory distilled water may bias upwards digestibility coefficients compared to what is actually observed on the dairy operation. Thus, use of actual farm water being offered to the cow to conduct the in vitro gas production measurements may more accurately predict the ruminal fermentation, digestibility and total gas production. The use of a water treatment system had minimal influence on the measurements of ruminal fermentation and digestibility in this study. However, the use of a water treatment system may still benefit the animal separately from effects on ruminal fermentation while considering total bacterial count.

The second study demonstrated that dry matter intake, milk yield, fat yield, protein yield and 3.5% fat corrected milk FE were similar for cows fed different corn hybrid silage TMRs. Low ruminal pH and acetate molar percentage and high propionate molar percentage were reported with Starchy corn silage hybrid compared to both leafy floury corn silage hybrids but similar ruminal NH_3-N. Starchy corn silage hybrid was lower in CP, higher in starch, lower in sugar content, lower in starch digestibility and lower in fiber digestibility compared to both leafy-floury corn silage hybrids. Leafy floury corn silage hybrids supply more digestible fiber than the conventional starchy corn silage hybrid. This study showed that a low starch, high digestible fiber (dNDF) corn silage can maintain similar milk production compared to a high starch, low digestible fiber ration.

The third study demonstrated that monocropping of Vining soybean produced lower dry matter yield, lower digestible dry matter yield, lower non forage carbohydrate and lower milk T/ha compared to intercropping of Vining soybean and BMR grazing corn with monocropping of BMR grazing corn being intermediate. Intercropping of Vining soybean and BMR grazing corn for silage holds promised for producing highly digestible forage for dairy cows than monocropping. The optimal seeding ratio of Vining soybean to BMR grazing corn is between 67:33 and 50:50 based on DDM and milk T/ha from results of this study. Comparison of 60 and 90 d ensiling periods showed that the ensiling process is not completed at 60 d and should be at least 90 d or more before feeding to the cows.

The fourth study demonstrated that the row cropping of mixed seeds of corn and soybean at different seeding ratios affect the forage and nutrient yields when planted at late season. The greatest nutrient yields occurred with BMR grazing corn in combination with Big Buck 6 soybean at a seeding ratio of 65:35 compared to other seeding ratios and combination of MC 5300 corn and Large Lad RR soybean. Mixed cropping of a Big Buck 6 in conjunction with either corn grown for silage offers the potential for the production of high biomass with a highly digestible nutrient composition compared to Large Lad RR soybean. Forage studies evaluating silage quality should be for a minimum of 90 d to ensure that ensiling process is completed because the lactic acid concentrations were greatest at 90 d.

The fifth study demonstrated that seeding ratio of MC 5300 corn and Vining soybean at 67:33 produced higher fresh biomass yield and dry matter yield. Land equivalent ratio was greater for MC 5300 corn and Viking 2265 soybean at 67:33 or 50:50 seeding ratios of corn and soybean. The production of forage blends through intercropping of corn and soybean has the potential to yield greater quantities of digestible nutrients compared to monocropping.

The sixth study demonstrated that the main effect of corn on fresh, DM, DDM, CP, NDF, NFC and starch yield was higher for MC 5300 corn compared to BMR grazing corn. The main effect of soybean on Viking 2265 and Vining soybean was similar on DM, DDM, CP, NDF, NFC and starch yield. MC 5300 corn with either soybean produced higher fresh, DM and nutrient yields compared to BMR grazing corn. Corn and soybean seeding ratio at 65:35 produced more forage and nutrient yields compared to 55:45, 45:55, or 35:65 seeding ratios of corn and soybean respectively.

Overall, six studies discussed the impact of water source and quality on rumen fermentation, production response of new corn hybrids compared to conventional corn silage hybrid, and evaluation of different corn and soybean varieties with different proportion of corn and soybean seeds to produce quality forage blend under both conventional and organic forage production system.

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GLOSSARY

Acid detergent Lignin (ADL): is the percentage of plant material which is insoluble in 72% sulfuric acid. Lignin reduces digestibility and has been used to predict digestibility.

Acid detergent fiber (ADF): It is the percentage of fiber in a forage sample which is insoluble in a weak acid. It contains cellulose, lignin and silica, but not hemicellulose. It often is used to calculate digestibility, total digestible nutrient and/or net energy for lactation.

Acid detergent insoluble crude protein (ADICP): The protein bound to the acid detergent fiber fraction of the feed which has been heat damaged and unavailable to the animal

Brown midrib (BMR) corn: The corn which has a lower lignin content than normal silage corn varieties. The lower lignin content increases the fiber digestibility of the corn silage.

Crude protein (CP): it is a mixture of true protein and non-protein nitrogen which can be determined by measuring total nitrogen in feed sample multiplied by 6.25.

Dietary cation anion differences (DCAD): It typically includes two cations (K and Na) and two anions (Cl and S). DCAD (meq/100 g of dietary DM) = (% K/0.039 + % Na/ 0.023) – (% Cl/0.0355) + (% S/0.016)

Digestible dry matter (DDM): It is the portion of the dry matter in a feed that is digested by animals at a specified level of intake. A unit that measures the amount of feed animal consume minus the feces they produce.

Digestible energy (DE): A unit that measures an animal’s feed intake gross energy minus fecal energy.

Digestibility: It refers to the extent to which a feedstuff is absorbed in the animal body as it passes through an animal’s digestive tract.

Dry matter intake (DMI): It is the amount of dry matter consumed by the animal in 24 h period.

Digestible neutral detergent fiber (dNDF): It is the portion of the neutral detergent fiber digested by animals at a specified level of feed intake. It is expressed as a percent of dry matter.

Dry matter (DM): It is the percentage of feed that is not water. Feeds must be expressed on a dry matter basis to determine if a daily ration meets the animal's nutrient requirements.

Ensiled: It refers to the forage or plant materials preserved by anaerobic fermentation and typically stored in a bag, bunker, wrapped bale or upright silo.

Feed efficiency (FE): It is a simple measure to determine the relative ability of cows to turn feed nutrients into milk or milk components. In the simplest terms, it is the kg of milk produced per kg of dry matter consumed.

Forage blend: It is a mixture of two or more than two forages usually legume and non-legume.

Forage quality: It refers to the ability of forage to support desired levels of animal performance which is a function of voluntary intake, digestibility, and nutrient content.

Forage: It is a bulky food such as grass, silage or hay for consumed by ruminant animals.

In vitro: It generally refers to the technique of performing a given biological procedure in a controlled environment outside of a living organism.

Intercropping: It is the cultivation of two or more crops simultaneously on the same field.

In vitro dry matter digestibility (IVDMD): It is the portion of the dry matter in a feed that is digested by animals at a specified level of feed intake estimated through in vitro procedure.

In vitro true digestibility (IVTD): It is an anaerobic fermentation performed in the laboratory to simulate digestion in the rumen. The result is a measure of digestibility that can be used to estimate energy.

Land equivalent ratio (LER): The ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level.

Metabolizable energy (ME): Metabolizable energy equals the gross feed energy minus the energy lost in the feces, urine and gaseous product of digestion.

Mixed cropping: the growing of two crops intermingled together in the same field.

Mycotoxin: Mycotoxins produced on plants by fungi usually in drought condition during the growing, harvest or storage. Vomitoxin, zearalenone, aflatoxin, T-2 etc. are some examples.

Neutral detergent fiber (NDF): It is the percentage of fiber in a forage sample which is not soluble in neutral detergent solution. It represents the cells wall which is only partially digestible by animals and inversely related to voluntary intake.

Neutral detergent fiber digestibility (NDFD): It is the 30 or 48 h in vitro digestible fraction of neutral detergent fiber expressed as percentage of the neutral detergent fiber content of a feed sample.

Neutral detergent insoluble crude protein (NDICP): An estimate of the portion of the rumen undegradable protein that is potentially available to the animal.

Net energy for growth (NE_G): It is an estimate of the energy in a feed used for body weight gain once maintenance is achieved.

Net energy for lactation (NE_L): It is an estimate of the energy value of a feed used for maintenance plus milk production during lactation and for maintenance plus the last two months of gestation for dry, pregnant cows.

Net energy for maintenance (NE_M): It is an estimate of the energy in a feed used to keep an animal in energy equilibrium, neither gaining weight nor losing weight.

Net return: Net income from an investment after deducting all expenses from the gross income generated by the investment.

Non fiber carbohydrate (NFC): It represents all forms of digestible carbohydrates that are solubilized after boiling a feed sample in neutral detergent solution. It is an estimate of the rapidly available carbohydrates in ration. NFC = 100% - (CP% + NDF% + EE% + Ash%)

Non protein nitrogen (NPN): It refers to nitrogen in a feed sample that is not in the form of protein but can be used by the microbial population in the rumen or gastrointestinal tract to synthesize amino acids and proteins.

Nutrient requirement: It refers to the minimum amounts of nutrients necessary to meet an animal’s real needs for maintenance, growth, reproduction, lactation or work but does not include a safety margin in ration formulation.

Ration: It refers to the total amount of feed allotted to one animal for a 24 h period.

Row cropping: It refers to the cultivation of crop in rows wide enough to allow it to be tilled.

Ruminant: It refers to a suborder of even-toed, cud-chewing, hoofed animals that have a stomach with four complete cavities.

Silage additives/inoculant: It refers to the substances added during the ensiling process to enhance production of lactic acid and/or a rapid decrease in pH of the feed.

Silage: It refers to the forage/feed preserved by an anaerobic fermentation process in which lactic acid and volatile fatty acids produced by fermentation lower the pH of the silage.

Soluble protein (SP): It refers to the protein fraction that is rapidly broken down in the rumen.

Total digestible nutrient (TDN): It is the sum of crude protein, fat (multiplied by 2.25), nonstructural carbohydrates, and digestible NDF. TDN = (NFC × 0.98) + (CP × 0.93) + (FA × 0.97 × 2.25) + (0.75 × (NDF × IVNDFD/100) – 7)

Total dissolved solid (TDS): It comprises inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water.

Total mixed ration (TMR): It is a homogeneous mixture of mechanically mixed ration ingredients that typically combine forages and concentrates to optimize animal performance.

Undigetible neutral detergent fiber (uNDF): It is the undigested neutral detergent fiber residue after fermentation at a given length of time such as 24, 30, 48, 90, 120, 240 h. It is used to estimate neutral detergent fiber digestibility and is expressed as either a percentage of neutral detergent fiber or percentage of dry matter.

Volatile fatty acid (VFA): They are produced in large amounts through ruminal fermentation and are of paramount importance in that they provide greater than 70% of the ruminant's energy supply.

Water quality: It is a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics.

CURRICULUM VITAE

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Long-term Career goal

- Professional dairy nutritionist/consultant for dairy farmers

Education

- ***Ph.D. Dairy Cattle Nutrition***, South Dakota State University, May 2016
- ***M.S. Dairy Cattle Nutrition,*** South Dakota State University, July 2012
- ***M. S. Animal Science (Livestock production and Management)***, Tribhuvan University (TU), Nepal, December 2005
- ***B.S. Agriculture (Animal Science)***, TU, Nepal, December 2002

Professional Experiences

- Graduate Teaching/Research Assistant (August 2012 – May 2016), Department of Animal Science/ Dairy Science Department, South Dakota State University, Brookings, SD, United States
- Graduate Research Assistant (August 2010 - July 2012), Dairy Science Department, South Dakota State University, Brookings, SD, United States
- Manager/Assistant Manager (November 2006 - August 2010), SIMZU LLC, Baltimore, MD
- Technical Officer (August 2004 - November 2006), Regional Agricultural Research Station (RARS, Lumle), Nepal Agricultural Research Council (NARC), Ministry of Agriculture and Co-operative, Nepal.
- High school teacher (Dec 1998 – Dec 1999), Nawal English Boarding School, Pragatinagar, Nawalparasi, Nepal

Trainings/Tests/Certifications

- Feed Processing and Mixing Technology (FPMT), 2015, Northern Crops Institute, North Dakota State University, Fargo, ND, United States
- Small Molecules Mass Spectrometry(SMMS), 2014, Core Campus Mass Spectrometry Facility, Department of Chemistry and Biochemistry, South Dakota State University, Brookings, SD, United States
- Professional Animal Scientist (PAS), 2014, American Registry of Professional Animal Scientist (ARPAS), United States

- RNA Sequence Analysis (RNA-SA), 2014, iPlant Collaborative and Department of Plant Science, South Dakota State University, Brookings, SD, United States
- Micro-imaging Techniques(MIT), 2013, Functional Genomics Core Facility, Department of Biology and Microbiology, South Dakota State University, Brookings, SD, United States
- Certified Artificial Insemination Technician (CAIT), 2012, SDSU Extension Artificial Insemination School, Department of Animal Science, South Dakota State University, Brookings, SD, United States
- Working with the IACUC Curriculum Completion Certification, 2011, Collaborative Institutional Training Initiative (CITI), United States
- Certified Laboratory Animal Technician (LAT), 2009, AALAS, United States
- Servsafe Food Protection Manager Certification, 2008, United States
- Sustainable Livelihood Approaches in Agricultural Research (SLAAR), 2005, NARC, Nepal
- Participatory Rural Appraisal (PRA), 2003, TU, Nepal
- Social Mobilization and Community Development (SMCD), 2002, United Nations Development Program (UNDP)/ TU, Nepal

Awards and Grants

- Dairy Farmers of America Cares Foundation Scholarship (2016, Graduate Student Recipient), Dairy Farmers of America, Kansas City, MO, United States

- Second Annual Gamma Sigma Delta Poster competition, Ph.D. Poster (2016, Third place), Agricultural Honor Society, Gamma Sigma Delta South Dakota State University Chapter, Brookings, SD, United States
- Graduate Student Essay Competition (2015, First place), Graduate School, South Dakota State University. Essay selected to participate in National competition organized by USDA Outlook Forum Diversity Program, United States Department of Agriculture
- Graduate Research Grant Competition (2014, Grantee), Organic Forage Blend, Ceres Trust, Chicago, IL, United States
- Hoard's Dairyman Cow Judging Contest (2014, Second Place), SDSU Graduate Student team effort, IL, United States
- Graduate Research Award, Ph.D. Proposal (2013, First Place), Sigma Xi South Dakota State University Chapter, Brookings, SD, United States
- Graduate Research Award, M.S. Paper (2012, Second Place), Sigma Xi South Dakota State University Chapter, Brookings, SD, United States
- Academic Excellence Award, M.S. Animal Science (2005), Tribhuvan University, Nepal
- Graduate Research Scholarship (2003-2005), Institute of Agriculture and Animal Science, Tribhuvan University, Nepal
- Academic Achievement Scholarship (N, B.S. Agriculture (Animal Science) (2002), Nepal Animal Science Association (NASA), Kathmandu, Nepal
- IAAS Undergraduate Academic Scholarship (1999, 2000, 2001, and 2002), Tribhuvan University, Nepal.

Professional Affiliations/memberships

- American Association for the Advancement of Science (AAAS/Science)
- American Registry of Professional Animal Scientist (ARPAS)
- American Dairy Science Association (ADSA)
- American Society of Animal Science (ASAS)
- SDSU Dairy Club
- American Association for Laboratory Animal Science (AALAS)
- Nepal Animal Science Association (NASA)
- Gamma Sigma Delta (GSD), The Honor Society of Agriculture

Research and Farm Experiences

- Involving in several researches to produce highly digestible nutritious forage blend, as a Ph.D. student
- Assisting major professor in developing new research project proposals and new academic curriculum, teaching undergraduate and graduate courses
- Working as an in vitro gas production system specialist at South Dakota State University
- Worked in research project testing effect of water quality in ruminal fermentation and digestion
- Completed several in situ digestibility trials with ruminally cannulated cows
- Completed different protein sources and concentration trial on lactating cows as a MS student
- Assisted in feed formulation and farm management activities

- Participated in research project involving use of non-conventional/alternative feed sources
- Developed specific technical and agronomic package for high yielding oat forage program
- Studied, and collected herbal plants from mountainous region and maintained at RARS, Lumle arboretum
- Worked with team in rapid calf growing research program
- Involved in dairy cattle infertility case studies
- Involved in goat nutrition and meat quality trial as a MS student
- Completed poultry production research with different feed prebiotics as undergraduate student

Publications

Acharya, I., D. P. Casper, and X. Gu. 2016. Nutritional quality of silage produced from a mixed cropping system for ruminant livestock. Forage Focus. Midwest Forage Association. March. pp 20-21.

Acharya, I., X. Gu, and D. P. Casper. 2015. Forage yield, quality and digestibility when intercropping vining soybean with Mastergraze seed corn at different seeding rates. Forage Focus. Midwest Forage Association. August. pp 20-21.

Acharya, I. P., M. Kirk, and D. P. Casper. 2015. Lactational performance of early lactation high producing dairy cows fed corn silage produced by different seed corn hybrids. J. Dairy Sci. 98 (Suppl. 2): 384 (Abstr.).

Acharya, I. P., and D. P. Casper. 2015. Late season forage yield, quality, and digestibility from mixed cropping of organic certified corn and soybean hybrids at different seeding rates. J. Dairy Sci. 98 (Suppl. 2): 687 (Abstr.).

Acharya, I. P., D. P. Casper , X. Gu, and A. Charif. 2015 Forage yield, quality, and digestibility when intercropping vining soybean with Mastergraze seed corn at different seeding rates. J. Dairy Sci. 98 (Suppl.2): 287 (Abstr.).

Acharya, I. P., D. J. Schingoethe, K. F. Kalscheur, and D. P. Casper. 2015. Response of lactating dairy cows to different concentrations and sources of dietary protein on dry matter intake, milk production, milk composition, and amino acids status. Canadian J. Anim. Sci. 95: 267-279.

Casper, D.P., and I. P. Acharya. 2014. Evaluation of MegaFerm Fiber to enhance ruminal fermentation and nutrient digestibility of a total mixed ration using an in vitro gas production measurement system. J. Anim. Sci. 92 (Suppl. 2): 355 (Abstr.).

Casper, D.P., and I. P. Acharya. 2014. The influence of source and quality of water and water treatment system on the ruminal fermentation and nutrient digestibility of a total mixed ration using an in vitro gas production measurement system. J. Anim. Sci. 92 (Suppl. 2): 799 (Abstr.).

Acharya, I. P., D. J. Schingoethe, K. F. Kalscheur, and D. P. Casper. 2012. Response of different concentration and sources of dietary protein on blood urea nitrogen concentrations and plasma amino acid utilization for milk production. J. Dairy Sci. 95 (Suppl. 2): 41 (Abstr.).

Acharya, I. P., D. J. Schingoethe, and K. F. Kalscheur. 2012. Response of different concentrations and sources of dietary protein on lactating dairy cows**.** J. Anim. Sci. 90 (Suppl. 2): 121 (Abstr.).

Language Proficiency

- Fluency in Nepali, Hindi, Urdu and English

Computer and other Proficiency

- Microsoft Office (Word, Excel, Power point, Outlook)
- Statistical Package (Genstat, SPSS for window, MSTATC, SAS, R-programming)
- Feed formulation software (AminoCow, NittanyCow, NRC ration evaluator, AMTS)
- Micro-imaging (Digital Photography and Photoshop, Fluorescence Microscopy, Confocal Microscopy)
- Mass Spectrometry (Quadrupole MS, Tandem MS, Linear ion trap MS, Coupling MS with liquid chromatography, Coupling MS with gas chromatography)
- RNA Sequence Analysis (Sequence quality control, Mapping/alignment to the reference, Assembly of transcripts, Differential expression analysis)

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