INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 4, No. 5, p. 65-74, 2014

RESEARCH PAPER

# Maize managed on diverse cropping systems and N supply on yield and quality of maize stover silage

**[1,3]Akim T. Omokanye, [1]Frank M. Kelleher and [2]Alison McInnes**

*[1] Centre for Horticulture and Plant Sciences, University of Western Sydney, Building J4, Hawkesbury Campus, Locked Bag 1797, Penrith South DC NSW 1797, Australia*

*[2]School of Environment and Agriculture, University of Western Sydney, Building K29, Hawkesbury Campus, Locked Bag 1797, Penrith South DC NSW 1797, Australia*

*[3]Peace Country Beef & Forage Association, Grande Prairie Regional College, Box 3000, Fairview, Alberta, T0H 1L0, Canada*

**Article published on May 15, 2014**

**Key words:** Maize, cropping systems, silage yield, silage quality, livestock nutrition.

## Abstract

Maize stover can be an inexpensive source of forage for ruminant livestock, which may be grazed, stacked or ensiled. In the present study, maize stover was evaluated for silage yield and quality in five cropping systems using three rates of N fertilizer (0, 60 and 120 kg N ha$^{-1}$). The cropping system (CS) treatments consisted of cereal-legume (CS1, CS2 and CS3), cereal-cereal (CS4) or cereal-bare fallow (CS5) rotations. The study was part of a series of experiments conducted at Richmond in New South Wales, Australia, to examine the performance of soil, crop, animal (feed evaluation only) and economic components of cropping systems. For feed evaluation purpose, ensiling maize stover at maize grain harvest resulted in the highest silage yields from the CSs that included a legume in the rotation (CS1 and CS3). Silage yields showed significant and positive responses to the application of N fertilizer for all CSs. Silage quality for feeding ruminant animals was highest in terms of CP, P and Ca contents, Ca:P ratio and dry matter intake, for the maize-legume silages made from CS2 and CS3. Maize silage quality is discussed in relation to livestock nutrition requirements.

* **Corresponding Author:** Akim T. Omokanye ✉ aomokanye@gprc.ab.ca

## Introduction

Assuring adequate quantities of quality feed throughout the year is a major challenge for ruminant livestock production in most parts of the world. Maize stover can be an inexpensive source of forage, which may be grazed, stacked or ensiled (Bareeba *et al.*, 1993). Preservation of maize stover as silage makes it possible to retain plant nutrients that would otherwise be lost through respiratory breakdown in living plant tissues or by leaching, thereby producing a higher quality ration for growing animals. Ensiling maize stover after grain harvest is feasible, because it normally contains a considerable amount of moisture (62-68%, Linn and Martin, 1999), which is necessary for the ensiling process.

Maize silage is an important source of digestible effective fiber and can be an economical source of energy in diets for lactating cows. (Allen, 2009) and increase animal performance, while having the potential to reduce production costs (Phipps, 1994). Although cereal-based silages have a high energy content, they are low in crude protein (CP) when compared with grass silage (which they often replace), and therefore require protein supplementation for milk or meat production. Over the years, legumes (particularly dual-purpose types) have long been recognized as a good source of CP (Omokanye *et al.*, 2001; Omokanye *et al.*, 2003). For example, some high yielding dual-purpose varieties of cowpea maintain a high percentage of protein-rich green forage after grain harvest, and regrowth can be substantial, given sufficient residual soil moisture (Omokanye *et al.*, 2003). Legume residues can be used for grazing, harvested as green forage, or ensiled and used to complement high-energy maize silage. Alternatively, ensiling good quality forage legumes in combination with maize can improve the nutritional quality of maize silage and obviate the need for protein supplements (Bareeba *et al.*, 1993).

Nutrient analysis of forage is necessary for adequately balancing rations and calculating least cost rations. Crude protein content is always an important consideration in rations and is usually the most costly ration component. The objective of this research was to investigate the effects of cropping system (CS) and N fertilizer on the yield and quality of silage made from sole maize (CS1, CS4 and CS5), maize-lucerne (CS2) or maize-cowpea (CS3) mixtures at three N rates, over two maize cropping phases.

## Materials and methods

### *Experimental site*

The experiment was conducted from 2001 to 2003 at the Centre for Horticulture and Plant Sciences, Field Study Unit, University of Western Sydney, Richmond, Australia (33° 62'S, 150° 75'E, 21 m a.s.l. elevation). Soil has been classified as poorly structured orange to red clay loams, clays and sands (Bannerman & Hazelton, 1990). It was composed of 84% sand, 4% silt and 12% clay. The weather conditions at the site during the trial period, including conditions for the period of growth of a preceding maize crop in the summer of 2000-2001, are detailed in Fig. 1. The soil at the site had a soil pH of 5.8, 0.40 % organic matter, 0.08% N (Kjeldahl analysis) and17.0 mg $kg^{-1}$ P.

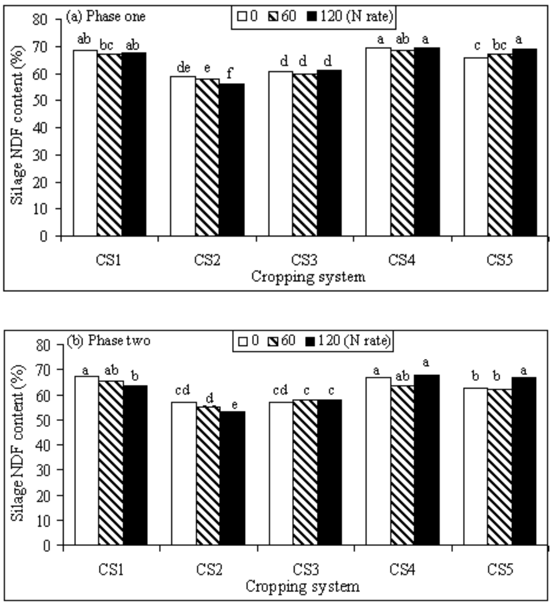

**Fig 1.** Effect of CS and N rate on silage NDF content in (a) phase one and (b) phase two. Bars with different letters are significantly ($P<0.05$) different according to LSD (1.9 - phase one; 2.3 - phase two).

*Experimental design, description of cropping systems and crop management*

The experimental design was a split-plot with five CSs as main-plots and three inorganic N fertilizer rates as sub-plots, with three replications. The CSs consisted of cereal-legume (CS1, CS2 and CS3), cereal-cereal (CS4) or cereal-bare fallow (CS5) rotations. The cereals used were maize and barley and the legumes were cowpea, lucerne and field pea. Details on the establishment and management of these crops have been provided in Omokanye (2004). The CSs incorporated both summer and winter cropping seasons within an annual cropping phase (Table 1).

**Table 1.** Description of cropping systems (CSs) showing crop species, rotations, growing season and specific comments

| | **Period of planting** | | | | |
|---|---|---|---|---|---|
| | **Cropping Phase one** | | | **Cropping Phase two** | |
| | **2000-01** | **2000** | **2001-02** | **2002** | **2002-03** |
| | **N-F**[1] | **J-N** | **N-F** | **J-N** | **D-M** |
| **Cropping systems:** | **Summer** | **Winter** | **Summer** | **Winter** | **Summer** |
| Maize/field pea (improved fallow, CS1) | maize | field pea[2] | maize | field pea | maize |
| Maize-lucerne/barley-lucerne (legume fodder bank, CS2) | maize | B-L[3] | M-L[4] | B-L | M-L |
| Maize-cowpea/field pea (CS3) | maize | field pea[5] | M-C[6] | field pea | M-C |
| Maize/barley (CS4) | maize | barley | maize | barley | maize |
| Maize/bare fallow (CS5) | maize | fallow | maize | fallow | maize |

[1] Months, N-F, November-February; J-N, June-November; D-M, December-March

[2] Field pea used as green manure for subsequent summer maize crop

[3] B-L, barley-lucerne intercrop

[4] M-L, maize-lucerne intercrop

[5] Field pea harvested for grain

[6] M-C, maize-cowpea intercrop

**Specific comments on CSs:**

| | |
|---|---|
| CS1 - | The legume (field pea – *Pisum sativum*) was incorporated as green manure into the soil at early flowering, before the subsequent maize crop was planted |
| CS2 - | Lucerne (*Medicago sativa*) was planted in autumn 2000 after the first (baseline) maize crop to represent *Stylosanthes* spp. as a legume fodder bank or stockpile forage. The lucerne was intercropped with maize in summer and barley in winter |
| CS3 - | Annual double cropping phases comprising summer maize intercropped with cowpeas (*Vigna unguiculata*) and winter field peas grown for grain. |
| CS4 - | Continuous cereal based double cropping system |
| CS5 - | Maize (*Zea mays*) - winter fallow system |

For the winter crops, phases one and two comprised the May to November periods in 2001 and 2002 respectively. For the summer crops, these phases were November 2001 to February 2002 and December 2002 to March 2003 respectively. The maize sub-plots were three inorganic N fertilizer rates: 0, 60 and 120 kg N ha$^{-1}$ (referred to below as N0 control, N60 and N120 respectively) applied as Nitram ($NH_4NO_3$, 34% N). The experiment received supplementary (sprinkler) irrigation as outlined in Omokanye (2004).

*Plant sampling for silage*

The material for silage was obtained from the residues of phases one and two crops described in Omokanye (2004). Maize grain was harvested at the hard dough stage, (code 87) as described by Zadoks *et al.* (1974), and the residual stover was sub-sampled for silage. Harvested stover was weighed (without cobs), hand-chopped with a knife into 2-3 cm pieces and ensiled as described below. Cowpea residues from the maize - cowpea intercrop (CS3) (flowers and pods removed after grain harvest, as practiced by Nigerian small-holder farmers), and lucerne from the maize - lucerne intercrop (CS2), were each harvested to 2 cm height from two 1 m x 1 m quadrats, randomly placed within each intercropped plot. Harvested cowpea residues and lucerne biomass were weighed, hand chopped into 2-3 cm pieces and ensiled as described below.

*Silage preparation*

All hand-chopped sub-samples were wilted for 24 h in a glasshouse. At the ensilage stage (i.e. after wilting), chopped maize stover had an average moisture content of 60% in phases one and two. After wilting, 1.5 kg samples from each plot were tightly packed into black plastic bags of 200 µm wall thickness and sealed, taking care to exclude as much air as possible to promote anaerobic conditions for successful ensilation. For CS2 and CS3, the maize stover and legume components harvested from each plot were mixed in proportion to their respective residue or lucerne biomass yields before ensilage began. The sealed plastic bags were packed in plastic drums that were closed tightly, and then opened after 28 d. Ensiled samples were weighed to determine the fresh yield of fermented silage. The silage was then oven-dried at 70°C for 48 h and later used for chemical analyses as detailed below. Total silage DM yield from each plot was calculated as the subsample silage DM yield multiplied by total harvested residue or lucerne biomass yields.

*Chemical analyses*

The oven-dried silage was ground to pass through a 0.75 mm mesh for mineral element analysis and a 1.00 mm mesh for NDF (Neutral Detergent Fibre) and ADF (Acid Detergent Fibre) analyses. Methods of determining mineral element contents have been described in Omokanye *et al.* (2011). NDF and ADF were determined by procedures outlined by Goering and van Soest (9). The formulae for estimating CP, DDM (Digestible Dry Matter) and DMI (Dry Matter Intake) from N, ADF and NDF respectively (10) were:

1. CP (DM basis) = % N (DM basis) * 6.25

2. % DDM = 88.9 - (0.779 x % ADF) (Undersander and Moore, 2002)
3. %DMI = 120 / % NDF (Undersander and Moore, 2002)

*Statistical analyses*

Data were analysed using the GLM procedure from the SAS computer package (SAS, 1997) to determine cropping system (CS) and N fertilizer rate main and interaction effects on all parameters. Where ANOVA indicated significant CS or N rate effects, means were compared by least significant difference (LSD) using the LSD lines of SAS procedure. For CS x N rate interaction effects, LSDs were calculated using the appropriate standard error terms described by Gómez and Gómez (1984). Significant differences between treatment means mentioned in the text refer to $P<0.05$.

## Results

*Silage yield*

No significant interactions were observed between CS and N rate on silage yield in either phase. Silage yield, averaged over N rate, was similarly and significantly affected by CS in both phases (Table 2). The CSs that included field peas in the rotation (CS1 and CS3) had significantly higher silage DM yields than those without legumes (CS4 and CS5) in both phases. Silage DM yield was highest for the maize only (CS1) and maize-cowpea intercrop (CS3) in phase one and for CS3 in phase two. The lowest silage DM yield was obtained for CS2 (maize - lucerne) in phase one and for CS2, CS4 and CS5 (maize only) in phase two. Both CS4 and CS5 had similar silage yields within each phase. Silage DM yield ranged from 7.9 to 11.9 t $ha^{-1}$

in phase one and from 8.9 to 11.1 t ha$^{-1}$ in phase two. Averaged over CS, silage yields for the N60 and N120 rates were 37 and 62% higher than the N0 control in phase one (Table 2). In phase two, the corresponding increases were 48 and 76%.

**Table 2.** Mean silage DM (SDM), mineral contents, digestible dry matter (DDM) and dry matter intake (DMI) in relation to cropping system (CS) and N rate for both phases

| **Treat-ment** | **SDM t ha$^{-1}$** | **CP %** | **P %** | **K %** | **Mg %** | **Ca %** | **Ca P** | **DDM %** | **DMI %** | **SDM t ha$^{-1}$** | **CP %** | **P %** | **K %** | **Mg %** | **Ca %** | **Ca: P** | **DDM %** | **DMI %** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CS** | **Phase one** | | | | | | | | | **Phase two** | | | | | | | | |
| CS1 | 11.6a | 5.95c | 0.12b | 1.90 | 0.19 | 0.50c | 4.17a | 61 | 1.81b | 10.4b | 5.89b | 0.10b | 2.69b | 0.19 | 0.56c | 5.60a | 60 | 1.83b |
| CS2 | 7.90c | 10.25a | 0.20a | 2.01 | 0.23 | 0.62a | 3.10b | 58 | 2.08a | 9.10c | 10.1a | 0.21a | 3.26a | 0.23 | 0.82a | 3.91c | 56 | 2.17a |
| CS3 | 11.9a | 8.90b | 0.20a | 1.92 | 0.19 | 0.59b | 2.98b | 59 | 2.01a | 11.1a | 10.8a | 0.22a | 2.77a | 0.22 | 0.73b | 3.32c | 57 | 2.09a |
| CS4 | 9.40b | 4.90d | 0.09b | 1.98 | 0.17 | 0.44c | 4.89a | 60 | 1.74b | 8.90c | 4.31c | 0.10b | 2.42b | 0.17 | 0.41e | 4.10b | 59 | 1.82b |
| CS5 | 10.0b | 5.10d | 0.10b | 1.74 | 0.19 | 0.47d | 4.79a | 61 | 1.78b | 9.30c | 4.78c | 0.09b | 1.89c | 0.17 | 0.46d | 5.11ab | 60 | 1.87b |
| LSD0.05 | 0.64 | 0.83 | 0.05 | - | - | 0.02 | 1.20 | - | 0.21 | 0.69 | 1.07 | 0.06 | 0.41 | - | 0.03 | 1.00 | - | 0.20 |
| **N rate (kg ha$^{-1}$)** | | | | | | | | | | | | | | | | | | |
| 0 | 8.10c | 5.00c | 0.13 | 1.90 | 0.21 | 0.49 | 3.77 | 59 | 1.87 | 6.90c | 5.10a | 0.13 | 2.62 | 0.19 | 0.60 | 4.62 | 57 | 1.94 |
| 60 | 11.1b | 7.60b | 0.14 | 1.92 | 0.19 | 0.49 | 3.50 | 61 | 1.89 | 10.2b | 7.70b | 0.15 | 2.60 | 0.21 | 0.62 | 4.13 | 59 | 1.97 |
| 120 | 13.0a | 8.50a | 0.14 | 1.92 | 0.18 | 0.48 | 3.43 | 59 | 1.87 | 12.2a | 8.70a | 0.14 | 2.61 | 0.20 | 0.62 | 4.43 | 57 | 1.94 |
| LSD0.05 | 0.81 | 0.76 | - | - | - | - | - | - | - | 0.73 | 0.54 | - | - | - | - | - | - | - |

Means within a column with different letters are significantly ($P<0.05$) different according to LSD.

*Silage quality*

Crude Protein: Crude protein content was not significantly affected by CS x N rate interaction in either phase. When averaged over N rate, the inclusion of legumes in the silage (lucerne in CS2 and cowpea in CS3) significantly increased CP content compared to that of silage made from maize alone in both phases (Table 2). The average CP content of maize plus legume silage (CS2 and CS3) was 80 and 109% higher than that of maize-only silage (averaged over CS1, CS4 and CS5) in phases one and two respectively. For CSs with maize-only silage, CP was significantly higher in CS1 than in either CS4 or CS5, in both phases. Averaged over CS, silage CP increased with N application up to N120 in both phases (Table 2). Silage yields for the N60 and N120 rates were higher by 51 and 69% respectively than the N0 control yield in phase one. In phase two, the corresponding increases were 50 and 70%.

Silage mineral composition: No CS x N rate interaction effects on mineral element content were observed in either phase. Averaged over CS, mineral content was not affected by N application for any of the measured elements. Averaged over N rate, maize-legume silages (CS2, CS3) had similar and significantly higher P and Ca contents than maize-only silages (CS1, CS4, CS5) in both phases (Table 2). Mean silage Ca content was lowest for CS4 in both phases. Silage P content was similar for CS1, CS4 and CS5 in both phases. Mean Ca:P ratio, averaged over N rate, was significantly higher in the maize-only silages (CS1, CS4 and CS5) than in the maize – legume silages (CS2 and CS3) in phase one. Ca:P ratio was significantly lower for CS2, CS3 and CS4 than for CS1 in phase two. When averaged over N rate, mean silage K content was not significantly different between CSs in phase one. However, mean silage K content was significantly higher for CS2 (maize-lucerne) and CS3 (maize-cowpea) and lower for CS5 (maize-only silage) than for CS1 and CS4 in phase two (Table 2). When averaged over either N rate or CS, mean silage Mg content was not significantly different between treatments in either phase.

Silage dry matter intake (DMI) and digestible dry matter (DDM): The estimated DDM and DMI were not significantly affected by CS x N rate interaction in either phase. When averaged over either CS or N rate, mean estimated DDM was also not affected by CS or applied N in either phase. Mean DMI, averaged over N rate, was significantly higher for maize-legume (CS2 and CS3) silage than for maize-only silages (CS1, CS4 and CS5), all of which had similar DMI in both phases (Table 2). When averaged over CS, mean DMI was not significantly affected by N rate.

Silage detergent fibre contents: The CS x N rate interaction was significant for silage NDF in both phases, but not for ADF in either phase. NDF values were significantly higher in the maize-only silage (CS1, CS4 and CS5) than in maize-legume silage (CS2 and CS3) at all N rates in both phases (Figure 1). N rate showed few consistent trends, except for a significant reduction in NDF in CS2 and a significant increase in NDF in CS5, at N120 in both phases. Mean silage ADF, averaged over N rate, was significantly higher in the maize-legume silage (CS2, CS3) than in maize-only silage (CS1, CS4, CS5) in both phases (Figure 2). Mean silage ADF content averaged 40% where legumes were included and 36% without legumes in phase one, and 42% and 38% respectively in phase two. Neither NDF nor ADF contents, averaged over CS, were affected by N rate in either phase.

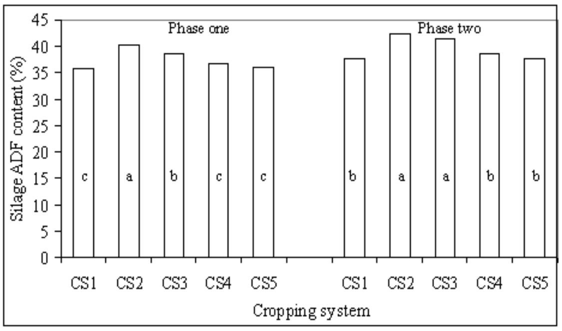

**Fig. 2.** Mean silage ADF content in relation to CS in phases one and two (averaged over N rate). Bars with different letters are significantly (P<0.05) different according to LSD (2.0 - phase one; 2.3 - phase two).

## Discussion

The suitability of a plant species for silage production is dependent upon its yield per unit area of land, its rate of DM accumulation, and its nutritional quality when made into silage.

The higher silage yield from maize-only in CS1 compared to CS4 and CS5 was attributed to the soil N build up from soil incorporation of field pea as green manure (see Omokanye *et al.*, 2011, 2013). The maize-cowpea intercrop (CS3) significantly out-yielded the sole maize (CS4 and CS5) and maize-lucerne (CS2) rotations in both phases, reflecting the stover yields reported earlier in Omokanye *et al.* (2013). CS2 performance, relative to CS4 and CS5, improved from phase one to phase two and this was attributed to a probable increase in N availability under the continuous lucerne intercrop over time Omokanye *et al.* (2011). The generally lower (except in CS2) silage yields in phase two could be attributed to differences in rainfall and temperature between the two phases, as reported for grain and stover in Omokanye *et al.* (2011). Similarly, the lower silage DM yield from CS2 compared to other CSs which included legumes (CS1 and CS3), could also be attributed to competition for water resulting from consistently lower soil water availability in this system (Omokanye *et al.*, 2011).

Ensiling maize stover would normally occur after grain harvest (Bareeba *et al.*, 1993). The late harvest would result in lower moisture content than the ideal value of 62-68% reported by Linn and Martin (1999). Though, the moisture content of maize stover harvested for silage in this experiment was lower (60-61%) than reported by Linn and Martin (1999), but the silage obtained in the present study smiled nice. To avoid further drops in moisture during the ensiling process, the use of preservatives on the maize stover is suggested.

High quality silage will result in better animal performance and reduce the need for other feed supplementation. Maize-legume (CS2, CS3) silage averaged 9.6 and 10.5% CP, compared to averages of 5.3 and 5.0% CP in maize-only (CS1, CS4 and CS5) silage in both phases one and two respectively. The higher CP contents of the maize-legume silages were attributed to N contribution from the legume component. These results are in agreement with the findings of Putnam *et al.* (1986), Martin *et al.* (1990)

and Carruthers *et al.* (2000), who reported higher CP contents in silage made from maize-legume intercrops than from maize-only silage. Considering the critical requirement of 6-8% CP in cattle diets (Humphreys, 1991), silage from CS2 and CS3 had adequate CP levels, but those from CS1, CS4 and CS5 were deficient in CP in both phases (see Table 3).

The CP adequacy of CS2 and CS3 in cattle diets demonstrates the potential of these systems to reduce or eliminate the requirement for purchased protein supplements, which would be of great benefit to smallholder farmers with limited resources. In the present study, the high CP content of maize-legume intercrop silages from CS2 and CS3 was similar to that reported by Anil *et al.* (2000), but CP content of the maize-only silages from CS1, CS4 and CS5 was lower than those reported (Anil *et al.*, 2000) for maize alone. The application of N60 and N120 rates increased CP content, averaged across all CS, to adequate levels for cattle nutrition.

Ensiling legumes with maize (CS2 and CS3) improved the supply of mineral nutrient elements, particularly P (both phases) and K (phase one only), when compared to silage made solely from maize. Maize-only silage from CS1, CS4 and CS5 had similar P and K contents, although CS5 had significantly lower values in phase two. Unlike CP, none of the mineral element contents were significantly affected by N fertilizer rate in either phase. P content in all silages was clearly below the critical requirements of 0.40-0.70% for young calves (Little, 1980) and 0.12% for young growing cattle (NRC, 2001), indicating the need for P supplementation. In contrast, K content of all silage was above the limiting values of 5-8 g kg$^{-1}$ DM (0.5-0.8%) for adult ruminant livestock (NRC, 1980, 2001, ADAS, 1984). The Mg content of all silages exceeded the minimum requirements of 0.07-0.10% for young calves (NRC, 2001) and 0.12-0.18% for sheep (NRC, 1980).

The significantly higher Ca content of silage from CS2 and CS3 compared to that from CS1, CS4 and CS5 in both phases was attributed to higher Ca content in the ensiled legume component, as reported earlier for legume crop residues at maize harvest (Omokanye, 2004). The differences in maize silage Ca content between CSs in phase one, and within CS between phases, was attributed to a yield dilution effect (Omokanye *et al.*, 2013). The Ca contents of silage from all CSs, with or without legumes, were mostly well above the minimum adult cattle requirement of 0.43% (ARC, 1980), although CS4 values (0.41 and 0.44%) were marginal in each phase. Ca contents for all CSs were within the range of 0.20-0.82% required by adult sheep (NRC, 1980). Ca content of silage from all N rates, averaged across CS, was adequate for growing and finishing calves, dry gestating and lactating beef cows (NRC, 2000). However, for young growing dairy calves, only the maize-legume silages from CS2 and CS3 met the critical requirement of 0.60-1.00% Ca (NRC, 2001).

The resulting Ca:P ratios of 3-5:1 (phase one) and 3-6:1 (phase two) (with CS2 and CS3 recording lower values than other CSs) far exceeded a generally assumed optimum ratio of 1-2:1 Ca:P (26). However, the higher Ca:P ratios of the maize-only silages (average overall 4.78 (4.62 phase one and 4.94 phase two)) compared to those of the maize-legume silages (3.30 (3.04 and 3.57 respectively)) would be less suitable for ruminant diets, particularly where the actual P content of silage from all CS was below the requirement of young growing animals. In this situation, the higher Ca:P ratio of the maize-only silages could exacerbate the marginal P status of diets based on silage from these CSs.

The DDM estimates for all silages were not affected by CS in either phase, and were generally well above 50%. Based on published forage quality standards (Schroeder, 1996), silage from all CSs was graded high (grade 1, 58-62% DDM), but was below the prime grade of >65% DDM. This study also showed that DMI, as expected, was higher for maize-legume silage (CS2 and CS3) than for maize-only silage in both phases. Based on the forage quality standards of Schroeder (1996), CS2 and CS3 ranked highest (grade 3), followed by CS1 (grade 4) and then CS5 (grade 5) in both phases. The higher DMI obtained from CS2 and CS3 was mainly due to their lower NDF content, which was attributed to their ensiled legume components.

Neutral detergent fibre (NDF) content is an indicator of how much of a forage an animal will eat. Although NDF was significantly affected by CS x N rate interaction in both phases, there was no clear trend in NDF levels within CSs in response to applied N. The most significant finding from an animal nutrition perspective was the lower NDF levels of the maize-legume silages from CS2 and CS3 compared to maize-only silage. This finding was consistent in both phases and indicates that livestock would eat more of the maize-legume than maize-only silage if samples were presented simultaneously in a feed preference trial. While lower NDF values indicate likely greater acceptance by animals, if they are too low, stomach upsets such as acidosis and displaced abomasums may occur in ruminant livestock (Robinson and Putman, 1998). However, the NDF values recorded in this study were well above the normal range required for dairy cattle diets of 25-33% (NRC, 2001). Unlike NDF, ADF was significantly higher for silages from CS2 and CS3 than for the other CSs in both phases. Similar findings have been reported for silage made from maize-runner bean and maize-sunflower intercrops compared to maize-only silage (Anil et. al., 2000). The ADF values recorded in this study were well above the required normal range for dairy cattle diets of 17-21% (NRC, 2001).

## Conclusion

Silage yields were greatest from the CSs that included a winter legume in the rotation (CS1 and CS3), and showed significant and positive responses to the application of N fertilizer for all CSs. Using the standard measures of quality such as CP, NDF and ADF, the presence of legumes in silage mixtures (CS2 and CS3) significantly improved silage DMI compared to maize-only silage (CS1, CS4 and CS5). Silage quality for feeding ruminant animals was highest for the maize-legume silages made from CS2 and CS3 in terms of CP, P and Ca contents, Ca:P ratio and DMI, and was suitable to meet the nutritional requirements of young, growing ruminant animals, provided a P supplement was included. No P supplement was required for adult ruminants. In contrast, silage made from maize only (CS4 and CS5) was below the required CP levels for feeding ruminants and would require the inclusion of a protein supplement, particularly for growing or lactating animals. Both Ca and P supplements would also be required for growth or lactation. Maize-only silage from CS1 had adequate CP for growth and lactation, reflecting the greater N availability from soil incorporation of field pea before maize was sown. In all other respects it was similar to maize-only silage from CS4 and CS5.

## Acknowledgments

The untiring technical support provided by Burhan Amiji, John Christie and Mark Emanuel from the School of Environment and Agriculture of the University of Western Sydney is appreciated. I thank the University of Western Sydney, Australia for the awards of International Postgraduate Research Scholarship (IPRS) and the Centre for Farming Systems Research for the Postgraduate Scholarship for my PhD program in Systems Agriculture with the University, without which this study would not have been possible.

## References

**ADAS (Agricultural Development and Advisory Service), MAFF, DAFS, DANI, UKASTA, BVA.** 1984. Mineral, trace element and vitamin allowances for ruminant livestock. ADAS, Wolverhampton.

**Anil L, Park J, Phipps RN.** 2000. The potential of forage-maize intercrops in ruminant nutrition. Animal Feed Science and Technology **86**,157-164.

**ARC (Agricultural Research Council)**. 1980. Nutrient Requirements of Ruminant Livestock. Farnham Royal, Bucks: Commonwealth Agricultural Bureaux.

**Bareeba FB, McClure KE.** 1993. Effect of ensiling maize stover with alfalfa or urea on intake, digestibility and nitrogen balance by growing lambs. Proceedings of theSecond African Feed Resources Network (AFRNET) Workshop, Harare, Zimbabwe, 6–10 December 1993.

**Carruthers K, Prithiviraj B, Fe Q, Cloutier D, Martin RC, Smith DL.** 2000. Intercropping of corn with soybean, lupin and forages: silage yield and quality. Agron Crop Science **185**,177-185.

**Goering HK, van Soest PJ.** 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). Agriculture Handbook 379. Washington DC, USA.

**Gomez KA, Gomez AA.** 1984. Statistical procedure for agricultural research. 2nd ed., John Wiley and Sons, NY.

**Humphreys LR**. 1991. Tropical Pasture Utilization. Cambridge University Press, Cambridge, UK. 206pp.

**Linn JG, Martin NP.** 1999. Forage Quality Tests and Interpretations. Forage Quality Tests and Interpretation, University of Minnesota Extension Service, St. Paul, Minn, USA.

**Little DA**. 1980. Observations on the phosphorus requirement of cattle for growth. Research in Veterinary Science **28**,258-260.

**Martin RC, Voldeng HC, Smith DL.** 1990. Intercropping corn and soybean in a cool temperate region: Yield, protein and economic benefits. Field Crops Research **23,** 295-310.

**Moore JE, Undersander D.** 2002. Relative Forage Quality (RFQ): Indexing Legumes & Grasses for Forage Quality. http://www.uwex.edu/ces/ forage/ pubs/rfq.htm

**NRC (National Research Council).** 2001. Nutrient requirements of dairy cattle, Seventh Revised Edition. National Research Council/National Academy Press, Washington, DC.

**NRC (National Research Council).** 2000. Nutrient Requirements of Beef Cattle. Seventh Revised Edition: Update 2000. Washington, DC: The National Academies Press.

**NRC (National Research Council).** 1980. Mineral Tolerance of Domestic Animals. National Research Council/National Academy of Sciences, Washington, D.C. 577p.

**Omokanye AT, Kelleher FM, McInnes A.** 2011. Low-input cropping systems and N fertilizer effects on crop production: soil nitrogen dynamics and efficiency of N use in maize crop. American-Eurasian J. Agric. & Environ. Sci. **11,** 282-295.

**Omokanye AT**. 2004. Biological and economic evaluation of maize-based cropping systems for Nigerian smallholders, PhD. Thesis, University of Western Sydney, NSW, Aust., March 2004. [Available online] http://arrow.uws.edu.au:8080/vital/access /manager/Repository/uws:797

**Omokanye AT, Kelleher FM, McInnes A.** 2013. Crop Residues for Mulch, Feed Yield and Quality as Influenced by Low-input Maize-based Cropping Systems and N Fertilizer. Agricultural Journal **8,** 222-231.

**Omokanye AT, Onifade OS, Olorunju PE, Adamu AM, Tanko, RJ, Balogun RO**. 2001. The evaluation of dual-purpose groundnut (Arachis hypogaea) varieties for fodder and seed production at Shika, Nigeria. Journal of Agricultural Science (Camb.) **136**, 75-79.

**Omokanye AT, Onifade OS, Amodu JT, Balogun RO, Kallah MS.** 2003. Evaluation of dual-purpose cowpea (Vigna unguiculata (L) Walp.) Varieties for grain and fodder production at Shika, Nigeria. Tropicultura **21**, 42-46.

**Phipps RH.** 1994. Complementary forages for milk production. In P. C. Garnsworthy and D. J. A. Cole, Eds., Recent advances in animal nutrition. Nottingham University Press, Loughborough, pp. 215-23.

**Putnam DH, Herbert SJ, Vargas A.** 1986. Intercropped corn-soyabean density studies. II. Yield composition and protein. Experimental Agriculture **22**, 373-381.

**Robinson PH, Putnam DH.** 1998. Interpreting Your Forage Test Report. California Alfalfa & Forage Review (Summer 1998) **1**, 2-3.

**SAS Inc.** 1997. The SAS system for Windows. Version: 6.12 North Carolina, USA: SAS Institute Inc.

**Schroeder JW**. 1996. Quality Forage for Maximum Production and Return. North Dakota State University. Retrieved from: http://www.ag.ndsu.edu/ pubs/ansci/range/ as1117w.htm [December 01, 2012].

**Singh BB, Tarawali SA.** 1997. Cowpea and its improvement: key to sustainable mixed crop/livestock farming systems in West Africa. In C. Renard, ed., Crop residues in sustainable mixed crop/livestock farming systems. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)(India) and International Livestock Research Institute (ILRI) (Kenya), CAB International (UK), pp. 79-100.

**Undersander D, Moore JE**. 2002. Relative forage quality (RFQ) indexing legumes and grasses for forage quality. University of Wisconsin Extension. Retrieved from: http://www.uwex.edu/ces/forage /pubs/rfq.htm [October 12, 2012].

**Underwood EJ**. 1981. The mineral nutrition of livestock. CAB International, Farnham, Royal, UK.

**Zadoks JC, Chang TT, Konzak CF**. 1974. A decimal code for the growth stages of cereals. Weed Research **14**, 415-421.