Agric Res (March 2013) 2(1):90–97
DOI 10.1007/s40003-012-0048-0

FULL-LENGTH RESEARCH ARTICLE

Intercropping Maize and Faba Bean for Silage Under Swedish Climate Conditions

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Received: 9 August 2012 / Accepted: 27 December 2012 / Published online: 20 January 2013

Abstract Cultivation of forage maize is increasing in Sweden. Sole maize is low in protein and supplementation of protein feed is needed. This study investigated whether forage maize and legumes can be intercropped in a system suitable for farmers (simultaneous sowing and harvest) under Swedish climate conditions, and whether intercropping maize and faba bean improves the forage quality compared with sole maize. Two field experiments were performed in which maize intercropped with faba bean (*Vicia faba* L.) in alternate rows with 0 or 60 kg N/ha was compared with sole maize crop with 120 kg N/ha. Maize dry matter (DM) yield decreased by intercropping (from mean 14,171 kg DM/ha for sole maize to 8,888–10,791 kg DM/ha for intercropped maize). Mean yield of faba bean ranged from 2,907 to 2,966 kg DM/ha. Compared with sole maize, intercropped treatments slightly increased forage protein content (mean increase 10–15 g/kg DM). Furthermore, intercropping increased forage in vitro organic matter digestibility by 4 % units (from 80.8 to 84.7 %), while the starch concentration slightly decreased from 316 to 236–254 g/kg DM. Intercropping increased neutral detergent fibre concentration from 435 to 478–497 g/kg DM and the sugar concentration from 57.3 to 61.5–72.3 g/kg DM. The results showed that intercropping silage maize and faba beans is possible under Swedish climate conditions.

Keywords Intercropping · Silage · Maize · Faba bean

Introduction

Crops that are adapted to warmer climates are increasing in Sweden due to changing climate conditions. Maize (*Zea mays* L.) for silage has attracted great interest in both organic and conventional production systems. New early maturing maize hybrids have contributed to an increasing maize acreage in Sweden from 4,000 ha in 2003 [33] to 16,200 ha in 2009 [1].

Maize has a high content of energy originating from digestible starch, sugars and fibres and is highly palatable to ruminants [29]. However, the crude protein content of maize forage is low so supplementation with protein feeds is needed to fulfil the protein requirements for producing ruminants. Diets have traditionally been supplemented with imported soybean meal. However, the production of soybean in South America may result in deforestation of rainforests and thus emissions of greenhouse gases. In addition, the long transport distance contributes to greenhouse gas emissions and is expensive. Therefore, locally produced forage protein such as peas and faba bean is desired. One way to increase the protein content in maize forage is by intercropping maize with legumes [9, 12, 25].

Many studies have confirmed the advantages of intercropping compared with monocropping, which include higher total yield per unit land area, resulting in a land

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equivalent ratio (LER) >1 [19, 25, 31]. However, in many of those studies the intercrops were sown and harvested at various points in time. Thus, the results are not practically applicable if farm machinery is to be used for silage production of intercropped forages. Crops for silage should be harvested simultaneously. Furthermore, simultaneous sowing is preferred under Swedish climate conditions, as optimal sowing conditions often only prevail during a short period of time in spring. Intercropping maize and legumes for silage with simultaneous harvesting, and in some studies simultaneous sowing, has been investigated with soybean (*Glycine max* L. Merr.) in Canada [26, 27], cow pea (*Vigna unguiculata* L.) in Iran [12] and various species of bean in the U.S. [6]. The results show that intercropping commonly contributes to higher protein content in the forage compared with sole maize and better yield (LER > 1) compared with monoculture. However, the bean cultivars used in earlier studies are not suitable for growing in the climate conditions prevailing in Sweden. Therefore, a crop such as faba beans (*Vicia faba* L.) may be an appropriate species to use. Faba bean is a late-maturing crop and may be suitable for intercropping and ensiling with maize under Swedish climate conditions.

The main objective of this study was thus to investigate whether silage maize and legumes can be intercropped in a manner suitable for practical farming (simultaneous sowing and harvest) under Swedish climate conditions. A further objective was to determine whether intercropping maize and faba bean improves the forage quality compared with sole maize.

Our starting hypotheses were that intercropping maize and legumes for silage: (i) is possible under Swedish climate conditions with both crops simultaneously sown and harvested and (ii) improves the forage quality by increasing the protein content.

Materials and Methods

Field Experiment Locations and Design

Two field experiments were performed in 2009 by the Field Research Unit of the Rural Economy and Agricultural Societies (HS Konsult AB, Örebro and Hushållningssällskapet, Kristianstad) as on-farm trials. Locations of the experiments were Knislinge in Skåne County in southern Sweden (55°51′N, 14°8E; ‘South’ location), and Odensbacken in Örebro County, central Sweden (59°9′N, 15°27′E; ‘Central’ location). Meteorological conditions are shown in Table 1. Composite topsoil samples were taken for determining pH (SS (Swedish standard)—ISO 10390), P-AL, K-AL (SS 028310/SS 028310T1), organic matter (KLK1965:1), soil texture (SS ISO 11277 mod.) and mineral-N (ADAS method 53) (Eurofins Food and Agri Sweden AB, Kristianstad). Soil properties in the South location: pH 7.8, OM 2.9 %, clay content 4 %, mineral-N (0–60 cm) 76 kg/ha, P-AL 230 mg/kg and K-AL 80 mg/kg, and in the Central location: pH 6.1, OM 4.6 %, clay content 25 %, mineral-N (0–60 cm) 210 kg/ha, P-AL 50 mg/kg and K-AL 20 mg/kg.

An early hybrid (FAO 190) of maize (*Z. mays* L. cv. Isberi) was either cultivated as a monocrop or intercropped with faba beans (*V. faba* L. cv. Marcel). Nitrogen was applied at 120 kg/ha in the maize monoculture, and application rates in the two intercropped treatments were 0 or 60 kg/ha. Thus, there were three treatments with four replicates each (in total 12 plots in each experiment), laid out in a randomised complete block design. Each plot consisted of four rows (each 12-m long and 0.75-m wide) of maize and thus the area of each plot was 36 m^2.

Cultivation Practice

The crops were sown on 2 May in the South and on 15 May in the Central experiment. The maize was cultivated in accordance with Swedish recommendations in all treatments, i.e., row spacing 0.75 m, seed rate 85,000 viable seeds/ha and sowing depth 0.04–0.05 m with a precision drill. In intercrop treatments, one row of legumes was sown between the maize rows with a precision drill and thus the row width was 0.375 m. The seed rate used for faba bean was 350,000 viable seeds/ha. The nitrogen was applied as a commercial fertiliser (YaraMila Pro Magna 8-5-19, Yara AB Sweden) with a ratio between the nutrients similar to that in animal manure, which is commonly used as fertiliser for maize in Sweden. Weed treatments were blind harrowing before emergence, 0.6 l/ha Basagran® SG (BAFS AB) when the faba bean plants were 30 mm tall, inter-row hoeing and manual weeding.

Harvest

The crops were harvested when the maize dry matter (DM) content was between 32 and 35 %, the optimum for silage

Table 1 Mean temperature (°C) and precipitation (mm) in May–Sept 2009 at the two field experiment locations

	South location		Central location	
	Temperature	Precipitation	Temperature	Precipitation
May	11.8	41	11.0	50
June	13.8	22	13.6	27
July	18.5	60	16.9	169
Aug	17.7	33	16.4	86
Sept	14.4	20	12.3	30

maize [8, 34], which occurred on 13 October in the Central location and 14 October in the South. In the South, where the area harvested in each plot was 15 m^2, the maize was harvested with a single row maize chopper with scale wagon (JF MH 30, Denmark) and the faba beans were harvested by hand and weighed on a field scale. In the Central location (harvested area 3.75 m^2), both crops were harvested by hand and weighed with a field scale. In the intercropped plots the crops were harvested separately. All plants were harvested at about 0.2 m above ground. At harvest, the faba bean was in maturity stage 97–99 in the South and in maturity stage 80–85 in the Central location [18, 39].

Sampling and Chemical Analyses of Crops

Crop samples were taken from each plot and chopped in the maize chopper (JF MH 30, Denmark) in the South location and with a compost mill (Stiga Bio Power 2100) in the Central. Thereafter, intercropped crops were mixed in the same ratio as the yield in three of the four blocks. Samples were taken from each of the three treatments (sole maize 120 N kg/ha, intercropped maize and faba bean 0 or 60 N kg/ha) and analysed for DM content at 105 °C for 16 h. Concentrations of starch, crude protein, ammonium nitrogen, neutral detergent fibre (NDF), in vitro rumen organic matter digestibility (IVOMD) and ash were determined on samples dried at 60 °C for 16 h and milled in a mill (Karnas Kvarnmaskiner AB, Malmö, Sweden) to pass through an 1-mm screen (Eurofins Food and Agri Sweden AB, Lidköping, Sweden). Crude protein concentration was determined as total-N concentration by the Kjeldahl technique in a Tecator Auto Sampler 1035 Analyser (Tecator Inc., Höganäs, Sweden). Ammonia-N concentration was determined using the Tecator Kjeltec Auto Sampler System 1035 Analyser. Starch was analysed by an enzymatic method according to Åman and Hesselman [3] and sugar was determined according to Ekelund [13]. The NDF was analysed according to Van Soest et al. [38]. IVOMD was determined by incubating dried, milled samples in rumen fluid and buffer at 39 °C for 96 h [2, 23]. Concentration of ash was determined at 550 °C for 16 h.

Silage Study

A pilot silage test was performed on forage from the treatment with sole maize and maize intercropped with faba beans +60 kg N in the Central location. Forage from three of the four replicates per treatment was used. The crops were chopped using a compost mill (Stiga Bio Power 2100). The chopped forage was packed in 1.7-l laboratory silos equipped with fermentation traps allowing CO_2 emission. The mean (SE) density of the forage was 186(8) kg DM/m^3. No silage additive was used. The jars were kept at 20 °C and weighed at ensiling and after 14, 43, 56, 67 and 90 days to monitor weight losses. Fermentation losses were calculated according to Weißbach [40].

After 90 days, the silos were opened and silage samples were frozen until later analysis of DM content, pH, ammonium nitrogen, organic acids (lactic, acetic, propionic and butyric) and ethanol (Eurofins Food and Agri Sweden AB, Lidköping, Sweden). The DM content of the silage was determined at 103 °C for 16 h and corrected for losses of volatile fermentation products according to Weißbach et al. [41]. The chemical analyses were performed on water extracts of fresh silage (20 g silage in 80 ml water for at least 2 h). Organic acids and ethanol were analysed by high pressure liquid chromatography [4]. Silage pH was determined using a pH electrode.

Statistical Analyses

Statistical analyses were performed by means of JMP 9.0 [16] using a mixed linear model, adjusted with 'treatment', 'location' and the interaction 'treatment × location' as fixed factors and 'block (location)' as a random factor. When the *F*-value was significant for the main effects and interactions of the fixed factors, pair-wise comparisons with Tukey's HSD-test were performed to identify significant differences ($p < 0.05$) among the treatment means. In the silage, test on material from the sole maize and maize intercropped with faba bean +60 N treatments was performed in the Central experiment. Data from all four replicates were used for the results on yield and three replicates were used for the chemical composition of the fresh forages and silages. A contrast analysis was used to determine differences between sole maize and the mean of the two intercropping treatments.

Results

Yield

The DM yield of maize and faba beans and the protein yield of sole maize and maize intercropped with faba bean is shown in Table 2. There were no significant differences for the interaction between the main effects (treatment × location, not shown). For the main effect of treatment, there were significant differences for maize yield. Sole maize had a higher DM yield (by 44–57 %) than intercropped maize.

For the main effect of location, significant differences were found for DM yield of faba bean, which was highest at the Central location.

There were no significant differences between the treatments in terms of number of maize plants, number of cobs and the presence of weeds (data not shown).

Table 2 Dry matter (DM) yield of silage maize and faba beans and protein yield in different cropping systems with various levels of nitrogen (N) as main effects of treatment and location

Main effects	Maize Yield (DM kg/ha)	Faba bean Yield (DM kg/ha)	Protein yield (kg/ha)
Average treatment, $n = 8$			
Sole maize 120 N[A]	14,171[a]		1,220
Maize + faba bean 0 N	8,888[b]	2,966	1,189
Maize + faba bean 60 N	10,791[b]	2,907	1,308
SEM	1,187	204	158
p (treatment)	*0.003*	*ns*	*ns*
Average location, $n = 12$			
South	10,497	2,459[f]	1,092
Central	11,872	3,416[e]	1,386
SEM	1,376	246	186
p (location)	*ns*	*0.041*	*ns*

ns Not significant

[A] Amount of nitrogen (kg/ha)

Different superscript letters within columns indicate significant differences ($p < 0.05$) between the treatments as a mean over locations (a and b for main effect of *treatment* and e and f for the main effect of *location*)

Forage Quality

A significant interaction was found for IVOMD and NDF concentration (Table 3). Maize intercropped with faba bean +60 N in the South and +0 N in the Central location had higher IVOMD than sole maize at both locations. The NDF concentration was higher in both intercrop treatments than in the sole maize in the South, whereas no differences in NDF concentration were found between treatments in the Central location. Sole maize had higher IVOMD and NDF concentrations in the Central location than in the South. In addition, both intercrop treatments had a higher NDF concentration in the Central location than in the South, whereas the differences in IVOMD between locations were not as evident. On average across locations, the starch concentration was higher, but the NDF concentration was lower for sole maize than for maize intercropped with faba beans +0 N. As a mean over treatments, DM and starch concentrations were higher, whereas NDF and IVOMD concentrations were lower in the South than in the Central location. The DM content of the faba beans was significantly higher in the South (66 %) than in the Central (48 %) location.

The contrast analysis showed differences in DM, ash, IVOMD, starch and NDF between intercropped forage and sole maize forage in the South location (Table 4). In the Central location, the forage only differed in IVOMD between intercropped and sole maize forage. There was also a tendency for increased crude protein content in the intercropped forage in the Central location ($p = 0.099$).

Silage Test

The fermentation losses increased most rapidly during the first 2 weeks of ensiling and they were 5.8 % in both treatments after 90 days of storage (Fig. 1). There were no significant differences in DM, CP, ammonia-N, pH, organic acids and ethanol between sole maize and maize intercropped with faba bean +60 N (Table 5).

Discussion

Intercropping Maize and Faba Beans in a Cool–Temperate Region

The results partly confirmed our first hypothesis, i.e. that it is possible to intercrop maize and legumes sown and harvested simultaneously for silage under Swedish climate conditions. The results showed that faba bean can be intercropped with maize.

In the present study, the maize yield was decreased by intercropping with the greatest reduction in the intercrop treatment without nitrogen (39 %). In intercropping +60 N kg/ha, the reduction in maize yield compared with sole maize was smaller (25 %). However, if the crops had been cultivated separately on an equally large area, the reduction in maize yield would have been 50 % since only half the area would have been cultivated with maize. This shows that intercropping can increase the land use efficiency. An explanation could be that the roots of the faba beans make available plant nutrients which can be assimilated by the maize [20, 21].

The amount of nitrogen added was lower in the intercropped treatments (0 and 60 N kg/ha) than in the sole maize (120 N kg/ha). However, the reduction in maize yield in intercropped treatments was less than the reduction in nitrogen rate, which indicates that intercropping may reduce the need for nitrogen fertiliser. Nitrogen transfer from faba bean to oats and from soybean to maize has been demonstrated [26, 35].

The relatively large differences in harvested area between the two field experiments might have affected the DM yield. However, there were no significant differences between the DM yield of maize between the two locations (Table 2). The yield of faba beans was higher in the Central location, which could be explained by later maturity and a higher amount of green leaves at harvest. The yield of faba bean was between 2,500 and 3,500 kg/ha (Table 2), which represented 19–26 % of the total forage DM yield in the intercropped treatments. As there was no treatment with sole faba bean, the effect of intercropping on faba bean yield could not be determined. However, it has been shown that faba bean growth may be facilitated when intercropped

Table 3 Forage quality parameters in different cropping systems with various levels of nitrogen (N)

Main effects and interaction	DM (%)	Ash (g/kg dm)	IVOMD (%)	Sugar (g/kg DM)	Starch (g/kg DM)	NDF (g/kg DM)	CP (g/kg DM)
Average treatment, $n = 6$							
Sole maize 120 N[A]	29.2	44.8	80.8^{b}	57.3	316^{a}	435^{b}	85.7
Maize + faba bean 0 N	31.5	50.5	84.7^{a}	72.3	236^{b}	497^{a}	100.3
Maize + faba bean 60 N	30.7	49.3	84.7^{a}	61.5	254^{ab}	478^{ab}	95.7
SEM treatment	1.03	2.80	0.52	7.9	18	14	5.1
p (treatment)	*ns*	*ns*	*0.002*	*ns (0.085)*	*0.046*	*0.026*	*ns (0.099)*
Average location, $n = 12$							
South experiment	34.5^{e}	44.2	81.0^{f}	50.6	321^{e}	427^{f}	90.0
Central experiment	26.3^{f}	52.2	85.8^{e}	76.9	216^{f}	513^{e}	97.8
SEM location	*1.3*	*2.9*	*0.50*	*8.2*	*13.2*	*13.7*	*4.4*
p (location)	*0.011*	*ns*	*0.002*	*ns*	*0.005*	*0.011*	*ns*
Average treatment × location							
South, $n = 3$							
Sole maize 120 N	31.5^{xy}	39.3	78.7^{z}	50.0	394	360^{y}	86.7
Maize + faba bean 0 N	37.4^{v}	48.0	81.0^{yz}	54.7	260	476^{x}	92.0
Maize + faba bean 60 N	34.6^{vx}	45.3	83.3^{xy}	47.0	310	433^{vx}	91.3
Central, $n = 3$							
Sole maize 120 N	26.8^{xy}	50.3	83.0^{xy}	64.7	237	510^{v}	84.7
Maize + faba bean 0 N	25.5^{y}	53.0	88.3^{v}	90.0	213	518^{v}	108.7
Maize + faba bean 60 N	26.8^{xy}	53.3	86.0^{vx}	76.0	197	512^{v}	100.0
SEM treatment × location	1.6	3.7	0.8	10.3	26	20	6.6
p (treatment × location)	*0.036*	*ns*	*0.050*	*ns*	*ns*	*0.046*	*ns*

ns Not significant

[A] Amount of nitrogen (kg/ha)

Different superscript letters within columns indicate significant differences ($p < 0.05$) between the treatments (a and b for the main effect of *treatment*, e and f for the main effect of *location* and v, x, y and z for the interaction *treatment* × *location*)

Table 4 Probability of difference (prob > Chi Sq) in a contrast analysis of sole maize compared with the mean for intercropping + 0 kg N and intercropping + 60 kg N for forage quality parameters in the two field experiments

Parameter	Location	
	South	Central
DM	0.037	ns
Ash	0.005	ns
IVOMD	0.004	0.012
Sugar	ns	ns
Crude protein	ns	ns (0.099)
Starch	0.018	ns
NDF	0.009	ns

ns Not significant

with maize compared with cultivation of the crops separately [14]. Nitrogen fertilisation did not have any effect on the yield of faba bean in the present study (Table 2), but it has been shown that addition of nitrogen can increase yield of faba bean [7, 24], or it can inhibit nitrogen fixation in legumes [36]. Intercropping may in turn alleviate the inhibitory effect of nitrogen fertilisation by increasing nodule biomass, which has been shown for faba bean intercropped with maize [22].

Forage Quality

The concentrations of the quality parameters in the sole maize treatment were comparable to the levels commonly found in maize silage [8].

The results partly confirmed our second hypothesis, i.e. that forage quality is improved by intercropping. There was a slight increase in protein content and IVOMD in the forage consisting of both crops in both experiments (Tables 3, 4). The starch concentration decreased and the NDF concentration increased or remained unchanged by intercropping. Javanmard et al. [17] and Sánchez et al. [37] also reported increased levels of crude protein but a decreased level of NDF in mixed silage of maize and other legumes such as soybean (*G. max*), vetch (*Vicia villosa*), bitter vetch (*Vicia ervilia*), berseem clover (*Trifolium alexandrinum*) and common bean (*Phaseolus vulgaris*) compared with sole maize silage. Higher dry matter

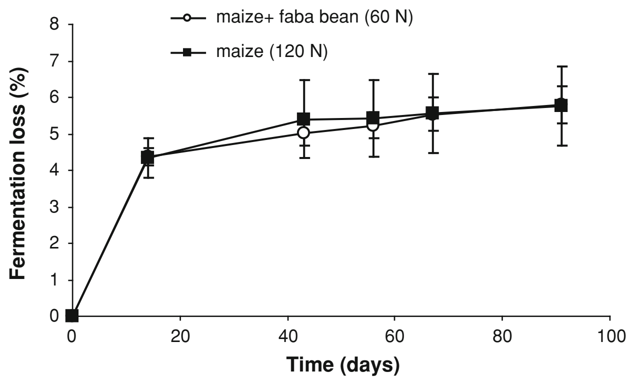

Fig. 1 Fermentation losses in laboratory silos with sole maize (120 kg/ha nitrogen) and intercropped maize + faba bean (60 kg/ha nitrogen)

Table 5 Fermentation characteristics in silage of sole maize and maize intercropped with faba beans, stored for 90 days

Forage quality parameter	Units	Treatment [crop and nitrogen (kg/ha)]	
		Sole maize 120 N	Maize + faba bean 60 N
DM	(%)	27.3	26.3
Crude protein	(g/kg DM)	82	98
NH_3–N[a]	(% of total-N)	8.10	10.63
pH		4.03	3.97
Lactic acid	(% of DM)	6.21	7.43
Acetic acid		0.91	1.61
Propionic acid		0.04	0.04
Butyric acid		0.59	0.30
Ethanol		1.06	1.08

[a] The level of NH_3–N was 1.2 % (sole maize) and 1.1 % (intercrop) of total-N in fresh herbage before ensiling

digestibility in silage of intercropped maize and faba bean compared with sole maize has been found previously in a sheep digestion trial [32], as confirmed by the results of the present study. The higher digestibility in intercropped forage may partly be due to the slight increase in sugar and crude protein content, as these nutrients are highly digestible (Table 3). The impact of intercropping on forage quality varies depending on factors such as plant species, plant density and stage of maturity of the crop at harvest [5, 10–12].

The differences in forage quality between the two field experiments are probably due to differences in stage of maturity of the maize and faba bean between the sites. The low starch and DM content and the high content of NDF in the Central location were probably due to immature maize with a high content of vegetative plant parts [8, 34]. The NDF content of maize in the Central location was probably closer to the NDF content of faba beans than of maize in the South, resulting in different effects of intercropping on the NDF content of the forage. The reduction of starch owing to intercropping could be explained by low starch levels in the stalks and leaves of faba bean, while the beans of faba bean have a starch content of 380–420 g/kg DM, which is similar to that of maize [15, 28]. The higher DM yield of faba bean in the Central location resulted in numerically higher protein yield even though mature beans have a higher protein content (approx. 274 g/kg) than green parts (approx. 190 g/kg) [30]. Addition of faba bean to maize silage did not significantly change the fermentation characteristics compared with sole maize (Table 5). Although not statistically significant, there was a numerical increase in crude protein and ammonia-N concentration in intercropped silage compared with sole maize. A reason why the differences in forage parameters were not greater between sole maize and intercropped forage could have been the method of sampling. There was a great difference in dry matter content between the crops at harvest with the volume of maize being much greater than that of faba bean. The presence of a piece of bean plant in the sample could make a great difference, thus thorough mixing of the crops before sampling is important.

In order to increase the yield of faba bean, and thereby the protein yield, sowing time of the faba bean could be delayed [9], but this technique involves a risk of the soil becoming too dry in spring, which may result in that the faba bean may not emerge at all. It should be noted that in the present study, the sowing time for faba bean was already delayed by almost 1 month compared with the normal time for cultivation of faba bean in Sweden. A more suitable alternative would probably be to use an earlier maturing maize hybrid, with a lower FAO number, making earlier harvest possible.

The choice of legume species has to be adapted according to the climatic conditions in the present location. For successful silage production, the intercropped species should have similar growth and maturity timing. In other agro-ecological zones, with warmer climate conditions and a greater number of possible legumes present, other species may be more suitable for intercropping with maize to silage than faba beans.

Conclusions

This study showed that maize and faba bean can be intercropped with simultaneous sowing and harvesting under Swedish climate conditions. The organic matter digestibility of the forage was improved by intercropping maize and faba beans. A late-maturing variety of faba bean together with an early maturing hybrid of maize may be suitable. Further investigations are required to determine how the management practices for intercropping maize and faba bean can be optimised for production of silage.

Acknowledgments This work was funded by The Swedish Farmers' Foundation for Agricultural Research.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. ABS (Agricultural Board of Sweden) (2010) Use of agricultural land 2009. Final Statistics. Sveriges officiella Statistik, statistiska meddelanden. JO 10 SM 1001. 17 mars 2010. ISSN 1654–4048
2. Åkerlind M, Weisbjerg M, Eriksson T, Tøgersen R, Udén P, Ólafsson BL, Harstad OM, Volden H, (2011) Feed analyses and digestion method, chap. 5. In: Volden H. (ed) NorFor—the Nordic feed evaluation system. EAAP Publication No. 130, pp 41–54
3. Åman P, Hesselman K (1984) Analysis of starch and other main constituents of cereal grains. Swed J Agric Res 14:135–139
4. Andersson NR, Hedlund B (1983) HPLC analysis of organic-acids in lactic-acid fermented vegetables. Z Lebensm Unters Forsch 176:440–443
5. Anil L, Park J, Phipps RH (2000) The potential of forage–maize intercrops in ruminant nutrition. Animal Feed Sci Technol 86:157–164
6. Armstrong KL, Albrecht KA, Lauer JG, Riday H (2008) Intercropping corn with lablab bean, velvet bean, and scarlet runner bean for forage. Crop Sci 48:371–379
7. Babiker EE, El Sheikh EAE, Osman AJ, El Tinay AH (1995) Effect of nitrogen fertilization and viral infection on yield, tannin and protein contents and in vitro protein digestibility of faba bean. Plant Foods Hum Nutr 47:257–263
8. Bal MA, Coors JG, Shaver RD (1997) Impact of the maturity of corn for use as silage in the diets of dairy cows on intake, digestion, and milk production. J Dairy Sci 80:2497–2503
9. Bryan WB, Peprah SA (1988) Effect of planting sequence and time, and nitrogen on maize legume intercrop yield. J Agron Crop Sci 161:17–22
10. Contreras-Govea FE, Muck RE, Armstrong KL, Albrecht KA (2009) Fermentability of corn–lablab bean mixtures from different planting densities. Animal Feed Sci Technol 149:298–306
11. Contreras-Govea FE, Muck RE, Armstrong KL, Albrecht KA (2009) Nutritive value of corn silage in mixture with climbing beans. Animal Feed Sci Technol 150:1–8
12. Dahmardeh M, Ghanbari A, Syasar B, Ramroudi M (2009) Effect of intercropping maize (*Zea mays* L.) with cow pea (*Vigna unguiculata* L.) on green forage yield and quality evaluation. Asian J Plant Sci 8:235–239
13. Ekelund S (1966) Medelande 28, bilaga VIII. Statens lantbrukskemiska kontrollanstalt; (in Swedish)
14. Fan F, Zhang F, Song Y, Sun J, Bao X, Guo T, Li L (2006) Nitrogen fixation of faba bean (*Vicia faba* L.) interacting with a non-legume in two contrasting intercropping systems. Plant Soil 283:275–286
15. Fru-Nji F, Niess E, Pfeffer E, (2007) Effect of graded replacement of soybean meal by faba beans (*Vicia faba* L.) or field peas (*Pisum sativum* L.) in rations for laying hens on egg production and quality. J Poult Sci 44:34–41
16. Institute SAS (2010) ©SAS Institute Inc. SAS Institute, Cary
17. Javanmard A, Nasab ADM, Javanshir A, Moghaddam M, Janmohammadi H (2009) Forage yield and quality in intercropping of maize with different legumes as double cropped. J Food Agric Environ 7:163–166
18. Lancashire PD, Bleiholder H, Langeluddecke P, Stauss R, van den Boom T, Weber E, Witzen-Berger A (1991) A uniform decimal code for growth stages of crops and weeds. Ann Appl Biol 119:561–601
19. Li L, Yang S, Li X, Zhang F, Christie P (1999) Interspecific complementary and competitive interactions between intercropped maize and faba bean. Plant Soil 212:105–114
20. Li L, Zhang F, Li X, Christie P, Sun J, Yang S, Tang C (2003) Interspecific facilitation of nutrient uptake by intercropped maize and faba bean. Nutr Cycl Agroecosyst 65:61–71
21. Li L, Li S-M, Sun J-H, Zhou LL, Bao X-G, Zhand H-G, Zhang F-S (2007) Diversity enhances agricultural productivity via rhizosphere phosphorus facilitation on phosphorus-deficient soils. PNAS 104:11192–11196
22. Li Y-Y, Yu C-B, Cheng X, Li CL, Sun J-H, Zhang F-S, Lambers H, Li L (2009) Intercropping alleviates the inhibitory effect on N fertilization on nodulation and symbiotic N_2 fixation of faba bean. Plant Soil 323:295–308
23. Lindgren E (1979) The nutritional value of roughages determined in vivo and by laboratory methods. Department of Animal Nutrition and Management, Swedish University of Agricultural sciences, Uppsala
24. López-Bellido RJ, López-Bellido L, López-Bellido FJ, Castillo JE (2003) Faba bean (*Vicia faba* L.) response to tillage and soil residual nitrogen in a continuous rotation with wheat under rainfed Mediterranean conditions. Agron J 95:1253–1261
25. Martin RC, Voldeng HD, Smith DL (1990) Intercropping corn and soybean for silage in a cool–temperate region: yield, protein and economic effects. Field Crop Res 23:295–310
26. Martin RC, Voldeng HD, Smithe DL (1991) Nitrogen transfer from nodulating soybean to maize or to nonnodulation soybean in intercrops: the ^{15}N dilution method. Plant Soil 132:53–63
27. Martin RC, Astatkie T, Cooper JM (1998) The effect of soybean variety on corn-soybean intercrop biomass and protein yields. Can J Plant Sci 78:289–294
28. Masoero F, Pulimeno AM, Rossi F (2005) Effect of extrusion, expansion and toasting on the nutritional value of peas, faba beans and lupins. Ita J Anim Sci 4:177–189
29. Masoero F, Rossi F, Pulimeno AM (2006) Chemical composition and in vitro digestibility of stalk, leaves and cobs of four corn hybrids at different phonological stages. Ita J Anim Sci 5(215): 227
30. Mihailović V, Mikić A, Ćupina B (2007) Potential of annual legumes for utilisation in animal feeding. Biotechnol Animal Husb 23:573–581
31. Morgado LB, Willey RW (2008) Optimum plant population for maize–bean intercropping system in the Brazilian semi-arid region. Sci Agric (Piracicaba, Braz) 65:474–480
32. Murphy WM, Welch JG, Palmer RH, Gilman BE, Albers CW, Dugdale DT (1984) Digestibilities of silages made from corn interplanted with soybean or faba bean. J Dairy Sci 67:1532–1534
33. Persson D, (2007) Uppgifter ur Lantbruksregristret, Jordbruksverket; (in Swedish)
34. Phipps RH, Sutton JD, Beever DE, Jones AK (2000) The effect of crop maturity on the nutritional value of maize silage for lactating dairy cows. 3. Food intake and milk production. Animal Sci 71:401–409
35. Purnamawati H, Schmidtke K (2003) Nitrogen transfer of two cultivar faba bean (*Vicia faba* L.) to oat (*Avena sativa* L.). Bul Agron 31:31–36
36. Salvagiotti F, Cassomn KG, Specht JE, Walters DT, Weiss A, Dobermann AR (2008) Nitrogen uptake, fixation and response to fertilizer N in soybeans: a review. Field Crop Res 108:1–13
37. Sánchez RGD, Silva JTE, Gil AP, Corona JSS, Wong JAC, Mascorron A (2010) Forage yield and quality of intercropped corn and soybean in narrow strips. Span J Agric Res 8:713–721

38. Van Soest PJ, Robertson JB, Lewis BA (1991) Methods for dietary fibre, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 74: 3585–3597
39. Weber E, Bleiholder H (1990) Erläuterungen zu den BBCH-Dezimal-Codes für die Entwicklungsstadien von Mais, Raps, Faba-Bohne, Sonnenblume und Erbse–mit Abbildungen. Gesunde Pflanz 42:308–321
40. Weiβbach F, (2005) A simple method for the correction of fermentation losses measured in laboratory silos. In: Park RS, Stronge MD (eds) Proceedings of the XIVth international silage conference, a satellite workshop of the XXth International Grassland Congress, July 2005, Belfast, Northern Ireland, p 278
41. Weiβbach F, Strubelt C (2008) Correcting the dry matter contents of maize silages as a substrate for biogas production. Landtechnik 2:82–83