The influence of intercropping maize with cowpea on the yield and quality of fresh fodder

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Abstract

Low cost and high dry-matter content are the reasons why cereals play an important role in feeding ruminant animals. Nevertheless, maize forage is poor in protein content, which leads to low quality and nutritive value. In view of the high feed costs of protein supplementations, legumes can be used in livestock nutrition for their high protein content, thereby providing cost savings. In this study, maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) were intercropped in various sowing densities and their monocropping equivalents were tested to determine the best intercropping system for fresh-fodder yield and quality. Maize was cultivated alone (75 000 plants·ha^{-1}) and intercropped with cowpea as follows: 75 000 plants·ha^{-1} of maize and 37 500 plants·ha^{-1} of cowpea (MC_1), 75 000 plants·ha^{-1} of maize and 50 000 plants·ha^{-1} of cowpea (MC_2), and 75 000 plants·ha^{-1} of maize and 75 000 plants·ha^{-1} of cowpea (MC_3) in rows alternating with maize. The highest dry-matter yield was produced by MC_3 (18.8 t·ha^{-1}) and the lowest by SM (16.9 t·ha^{-1}). All intercropped systems had higher dry-matter crude-protein content – MC_1 (99 g·kg^{-1}), MC_2 (108 g·kg^{-1}) and MC_3 (120 g·kg^{-1}) – than the monocrop maize (81 g·kg^{-1}). Intercropping of maize with cowpea reduced the neutral detergent fiber and acid detergent fiber content, resulting in increased forage digestibility. Intercropping maize with cowpea could substantially increase forage quantity and quality, and decrease requirements for protein supplements as compared with a maize monocrop.

Cowpea, intercropping, maize, quality, yield

Introduction

In many regions of Europe, whole-plant maize silage is the basic feed used for feeding cows and fattening cattle. Whole-plant maize silage is also the basic feed used for feeding dairy cows and fattening cattle in Croatia and plays a key role in supplying large quantities of digestive fibers and energy-rich forage in animal nutrition. Despite its high energy content, the protein content is low (88 g·kg^{-1}) compared with legume silage (Anil et al. 2000) and needs to be supplemented with proteins for better feed quality (Stoltz et al. 2013). As a cultivation system, intercropping involves planting two or more crop species in the same field (Kipkemoi et al. 2010; Costa et al. 2012). Intercropping maize with legumes for silage is a feasible strategy to improve the amount of crude protein (Prasad et al. 2005; Contreras-Govea et al. 2009; Zhu et al. 2011). Appropriate spatial arrangements, planting proportions and maturity dates of components in maize-legume intercropping enhance biological diversity and have many advantages over pure maize cropping. Although maize provides high yield in terms of dry matter, it produces low protein content in fodder. Cowpea, an annual legume with a high level of protein (about twice that of maize), can be mixed with maize to improve the forage protein content of diets and the costs of high-quality forage production can, therefore, be lowered. Javanmard et al. (2009) worked on the intercropping of maize with different legumes, and showed that the dry-matter yield and crude-protein yield of forage were increased by all intercropping compositions compared with the maize monocrop. Dahmardeh et al. (2009) concluded that intercropping maize and cowpea resulted in more digestible dry matter and higher crude-protein content than maize monocropping. Physiological and

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morphological differences between intercrop constituents influence their ability to use resources; cereals with legumes, in particular, have several advantages, such as higher overall yields, better soil utilization (Dhima et al. 2007), the yield stability of the cropping system (Lithourgidis et al. 2006), better use of light, water and nutrients (Javanmard et al. 2009), improved soil conservation (Anil et al. 1998), soil fertility through biological nitrogen fixation, increased soil conservation through greater soil coverage as compared to sole cropping, and ensure a better soil-susceptible crop in monoculture (Lithourgidis et al. 2006) and better control of pests and weeds (Banik et al. 2006; Vasilakoglou et al. 2008). Atmospheric nitrogen fixation using leguminous plants can reduce nitrogen competition in the reciprocal intercropping system of legumes and cereals enabling the cereals to use more nitrogen in the soil (Eskandari et al. 2009). This can affect the quality of the fodder intercrop components because the protein content is directly related to the content of nitrogen in the forage plants (Putnam et al. 1985). Cowpea is a late-maturing crop and can be suitable for intercropping and silage with maize in the climatic conditions in Croatia. This study was designed to determine the influence of different patterns of maize-cowpea intercropping on the yield and quality of fresh fodder.

Materials and Methods

A field experiment was carried out during the 2017 growing season at experimental fields in Bjelovar (45°54’36″N, 16°50’24″E), Croatia. Meteorological data for the experimental site are presented in Table 1.

Table 1. Air temperature and rainfall by month during the 2017 growing season

Meteorological data	Month					
	April	May	June	July	August	September
Air temperature [°C]	11.8	17.6	22.9	23.9	23.9	15.5
Rainfall [mm]	28.2	76.0	54.7	38.4	22.9	144.7

The experiment was set up as a randomized complete block design with three replicates. Maize hybrid seed (KWS Kolumbaris) was obtained from the seed company “KWS”. Seed of the cowpea cultivar “Dolga vigna” was obtained from the company “Sjemenarna”. The treatment comprising the individual plot size was 50 m × 2.8 m. The maize population of 75 000 plants ha^{-1} (SM) was spaced at 70 cm × 19 cm and the cowpea population of 37 500 (MC_1), 50 000 (MC_2) and 75 000 plants ha^{-1} (MC_3) was spaced at 70 cm × 38.1 cm, 70 cm x 28.6 cm and 70 x 19 cm, respectively, in rows alternating with maize. Basic tillage was carried out by ploughing to a depth of 30 cm. Presowing preparation was performed using a tractor-mounted rototiller. All plots were fertilized with the same amount of fertilizer before sowing, containing 200 kg of N·ha^{-1}, 100 kg of P_2O_5 ha^{-1} and 200 kg of K_2O ha^{-1}. Maize and cowpea were sown to a depth of approximately 5 cm by a maize drill on May 5th, 2017. The herbicide Wing P (active substances 212.5 g·l^{-1} dimethenamide-p and 250 g·l^{-1} pendimethalin) was applied pre-emergence to intercropping maize with cowpea at a dose of 4 l·ha^{-1}. The soil in the research area has an acid pH 4.8 reaction (M-KCl), humus (2.3%) poorly supplied with physiologically active phosphorous (9.3 mg P_2O_5/100 g soil), moderately supplied with physiologically active potassium (14.5 mg K_2O/100 g soil) and richly supplied with total nitrogen amounting to 0.20%. The fresh fodders were manually harvested when the maize reached the soft dough stage and the cowpea the R8 stage and were then chopped into 20 mm size pieces with a chaff cutter. The dry-matter content was determined by drying in an oven at a temperature of 65 °C to a constant mass. Crude protein was measured according to Kjeldahl (AOAC 2000), neutral detergent fiber and acid detergent fiber according to Van Soest et al. (1991), calcium and potassium were analyzed by atomic absorption spectrophotometry and phosphorus was analyzed by colorimetry (AOAC 2000). The water-soluble carbohydrate (WSC) was determined by the anthrone method using freeze-dried samples, with the WSC being extracted with water (Thomas TA 1977). Analyses of variance were conducted for fresh-fodder and dry-matter yield and forage quality parameters ($P < 0.05$), and the Tukey test was used for comparing means ($P < 0.05$). Data were analyzed using the statistical software SAS (SAS Inst. 2002).

Results and Discussion

Table 2 shows the yield of fresh fodder and dry matter of maize intercropped with cowpea. The differences in the yield of fresh fodder are statistically significant and those in the yield of dry matter are not statistically significant (P < 0.05). The yield of fresh fodder and the dry-matter yield ranged from 58.8 t·ha^{-1} (MC_3) to 43.7 t·ha^{-1} (monocrop maize) and 18.8 t·ha^{-1} (MC_3) and 16.9 t·ha^{-1} (monocrop maize) in 2017. The average yield of dry matter over the one year showed that MC_3 was the best intercropping production system with significantly higher yield of fresh fodder compared to monocrop maize (Table 2).

Table 2. Fresh-fodder, dry-matter and crude-protein yield of maize and maize-cowpea intercropped

	Treatments			
	SM	MC_1	MC_2	MC_3
Fresh-fodder yield in t·ha^{-1}	43.7d	46.9c	52.2b	58.8a
Content of dry matter in g·kg^{-1}	386a	366b	341c	321d
Dry-matter yield in t·ha^{-1}	16.9a	17.2a	17.8a	18.8a
Crude-protein yield in t·ha^{-1}	1.37c	1.70b	1.92b	2.26a

Different letters in a row mean a significant difference (P < 0.05)

According to the results, the fresh-fodder and dry-matter yields on the plot increased with the increasing number of cowpea seeds in intercrops. One of the possible explanations for the higher yields of intercrops is the ability of the crops to exploit different soil layers without competing with each other. Higher consumption of environmental resources, agronomic practices, crop genotypes, photosynthetic active radiation and soil moisture during the rainy season may also affect the yield and potential use of the intercropping system (Ofori and Stern 1987; Anil et al. 1998; Lithourgidis et al. 2006). Cowpea can be intercropped with maize (Dahmardeh et al. 2009) and sorghum (Azraf et al. 2007) for a higher yield and higher quality compared with sole cropping. Geren et al. (2008) and Htet et al. (2016) showed that the contribution of legumes to maize in mixtures was significant and increased the total biomass yield of the mixtures. One of the main reasons for intercropping maize and cowpea is the increased level of crude protein in the silage. Silage containing more crude proteins is desirable since crude proteins are extremely important in cattle fodder. This study found that the crude protein value of the intercropped fodders MC_1, MC_2 and MC_3 was statistically significantly (P < 0.05) higher than that of monocrop maize during the one-year study (Table 2). According to the results, the content of crude protein in the mixture increased when the number of cowpea seeds increased in the intercrops. Cowpea fodder is a rich source of crude protein, providing up to 184 g kg^{-1} (Khan et al. 2010). Furthermore, the protein content of cowpea forage (220 g·kg^{-1}) was higher compared to legumes such as lablab (*Lablab purpureus* L.), Mucuna (*Mucuna pruriens* L.) and grass species (*Sorghum sudanense* (Piper) Stapf), though it was the species least consumed by goats (Gwanzura et al. 2011). Dahmardeh et al. (2009) concluded that the maximum crude-protein percentage of forage was obtained at the milky stage and minimum crude protein was achieved at the dough stage of maize growth in maize-cowpea intercropping. The results of the present study were in agreement with other studies in which legumes also increased the crude-protein concentration when used in a mixture with maize (Dawo et al. 2007; Baghdadi et al. 2016; Erdal et al. 2016; Htet et al. 2016). This could be due to higher nitrogen availability for maize in intercropping compared with a monoculture crop (Eskandari et al. 2009). This study found that the yield of crude proteins in intercropped fodders MC_1, MC_2 and MC_3 was statistically significantly (P < 0.05) higher than monocrop maize during the one-year study (Table 2). Treatment MC_3 had the highest yield of crude protein of 2.26 t ha^{-1} in 2017 in comparison with other fodder mixtures (Table 2). From this point of view, the fodder produced in maize-cowpea intercrops is important not only to benefit from the increase in the content of crude protein, but also in view of the reduction of the content of neutral detergent fibers. For this reason, the best option in maize-cowpea intercropping is the use of cowpea genotypes that provide forage with the greatest amount of pods at harvest. In addition, the level of neutral detergent fibers is associated with the stage of maturity of the fodder due to the level of the cell-wall components, mainly cellulose, hemicellulose and lignin (Mugweni et al. 2000). The value of a neutral detergent fiber refers to the total cell wall and consists of an acid detecting the fiber fraction plus hemicellulose. This study found that the values of neutral and acid detergent fibers of intercropped MC_2 and MC_3 were statistically significantly ($P < 0.05$) lower than that of monocrop maize in the one year of the research (Table 3).

Table 3. Nutrient composition of maize and maize-cowpea intercropped fresh fodder ($g \cdot kg^{-1}$ dry matter)

Nutrient composition	Treatments			
	SM	MC_1	MC_2	MC_3
Crude protein	81c	99b	108ab	120a
Neutral detergent fiber	363a	343ab	329bc	316c
Acid detergent fiber	210a	195ab	184bc	174c
Ash	37a	44a	47a	50a
Potassium	5.2d	6.0c	6.2b	6.6a
Phosphorus	2.2c	2.3bc	2.4ab	2.5a
Calcium	3.6d	4.1bc	4.3b	4.6a
Water-soluble carbohydrate	141a	121b	114c	103d

Different letters in a row mean a significant difference ($P < 0.05$)

Neutral detergent fiber is a measure of the total content of fiber (hemicellulose, cellulose and lignin) in silage. The content of neutral detergent fiber is important in ration formulation because it reflects the amount of animal forage that animals can consume (Lithourgidis et al. 2006). In general, the concentration of neutral detergent fibers is higher for grass than for legumes (Dahmardeh et al. 2009). Acid detergent fibers are a subfraction of the neutral detergent fiber, which is composed primarily of lignin and cellulose and negatively correlated with the total digestibility of forage (Alfalfa Workgroup 1998). Since smaller amounts of fiber components are used for better digestion, the cowpea intercropped plots are superior to monocrop maize in terms of neutral detergent fiber and acid detergent fiber. The concentration values of acid detergent fibers are important because they describe the ability of the animal to digest forage. According to the results, when the number of seeds in cowpea rows increase in the intercrops, the values of neutral and acid detergent fibers in the mixture decrease. Similar results have been reported by Dahmardeh et al. (2009) and Htet et al. (2016). In this study, the potassium, phosphorus and calcium values of intercropped fodders MC_1, MC_2 and MC_3 were statistically significant ($P < 0.05$) in relation to monocrop maize during the one-year research (Table 3). According to the results, when the number of seeds of cowpea increased in intercrops, the ash, potassium, phosphorus and calcium content in the mixture increased. Azraf et al. (2007) and Basaran et al. (2017) state that the contribution of legumes with sweet sorghum in mixtures was significantly increased ash, potassium, phosphorus and calcium in fresh fodder. In this study, the water-soluble carbohydrate values of intercropped fodders MC_1, MC_2 and MC_3 were statistically significant ($P < 0.05$) in relation to monocrop maize during the one-year research (Table 3). According to the results, when the number of seeds of cowpea increased in intercrops, the water-soluble carbohydrate content in the mixture decreased.

Conclusions

The conclusion of the present study is that intercropping of maize with cowpea at various planting densities was shown to be an effective way of influencing fresh biomass production and dry-matter and crude-protein yield to enhance the nutrient quality of fresh fodder. Intercropping of maize with cowpea increased the values of crude protein, ash, potassium, phosphorus and calcium, and decreased the values of neutral detergent fiber, acid detergent fiber and water-soluble carbohydrate concentrations in fresh fodder. Finally, intercropping with 75 000 plants·ha^{-1} of maize and 75 000 plants·ha^{-1} of cowpea was most suitable according to the nutrient composition of the fresh fodder.

References

Alfalfa Workgroup 1998: Interpreting your forage test report. Calif Alfalfa Forage Rev. 2. Available at: http://www.foragetesting.org/files/InterpretingFQReport.pdf. Accessed December 18th 2015

Anil A, Park P, Phipps P, Miller M 1998: Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. Grass For Sci **53**: 301-317

Anil, L, Park, J, Phipps, RH 2000: The potential of forage-maize intercrops in ruminant nutrition. Anim Feed Sci Technol **85**: 157-164

AOAC (Association of Official Analytical Chemists) 2000: Official Methods of Analysis of AOAC International. 17th Ed, Washington DC

Azraf Ul Haq A, Riaz A, Naeem M, Tanveer A 2007: Performance of forage sorghum intercropped with forage legumes under different planting patterns. Pakistan J Botany **39** (2): 431-439

Baghdadi A, Halim RA, Ghasemzadeh A, Ebrahimi M, Othman R, Yusof MM 2016: Effect of intercropping of corn and soybean on dry matter yield and nutritive value of forage corn. Legume Res **39** (6): 976-981

Banik P, Midya A, Sarkar BK, Ghose SS 2006: Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. European J Agron **24**: 325-332

Basaran U, Copur Dogrusoz M, Gulumser E, Mut H 2017: Hay yield and quality of intercropped sorghum-sudan grass hybrid and legumes with different seed ratio. Turkish J Field Crops **22** (1): 47-53

Contreras-Govea FE, Muck RE, Armstrong KL, Albrecht KA 2009: Nutritive Value of Corn Silage in Mixture with Climbing Beans. Anim Feed Sci Technol **150**: 1-8. DOI: https://doi.org/10.1016/j.anifeedsci.2008.07.001

Costa PM, Villela SDJ, Leonel FDP, Araújo KG, Ruas JRM, Coelho FS, Andrade VR 2012: Intercropping of Corn, Brachiaria Grass and Leguminous Plants: Productivity, Quality and Composition of Silages. Revista Brasileira de Zootecnia **41**: 2144-2149

Dahmardeh MA, Ghanbari B, 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 **83**: 235-239 DOI: https://doi.org/10.3923/ajps.2009.235.239

Dawo MI, Wilkinson JM, Sanders FE, Pilbeam DJ 2007: The yield and quality of fresh and ensiled plant material from intercropped maize (*Zea mays* L.) and beans (*Phaseolus vulgaris*). J Sci Food Agric **87** (7): 1391-1399

Dhima, K, Lithourgidis, A, Vasilakoglou, I, Dordas, C 2007: Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Research **100**: 249-256. DOI: https://doi.org/10.1016/j.fcr.2006.07.008

Erdal S, Pamukcu M, Curek M, Kocaturk M, Dogu OY 2016: Silage yield and quality of row intercropped maize and soybean in a crop rotation following winter wheat. Archives Agronom Soil Sci. Available at: www.tandfonline.com/loi/gags20

Eskandari H 2012: Yield and quality of forage produced in intercropping of maize (Zea mays) with Cowpea (*Vigna Sinensis*) and Mungbean (*Vigna radiate*) as Double cropped. J Basic App Sci Res **2** (1): 93-97

Eskandari H, Ghanbari A, Galavi M, Salari M 2009: Forage Quality of Cowpea (*Vigna sinensis*) Intercropped with Corn (*Zea mays*) as Affected by Nutrient Uptake and Light Interception. Notulae Botanicae Horti Agrobotanici Cluj-Napoca **37**: 171-174

Geren H, Avcioglu R, Soya H, Kir, B 2008: Intercropping of Corn with Cowpea and Bean Biomass Yield and Silage Quality. African J Biotech **22**: 4100-4104

Gwanzura T, Ngambi JW, Norris D 2011: Effects of selected legumes species and forage sorghum hay grown in Limpopo Province on voluntary intake and relative palatability indices of pedi goats. Asian J Anim Vet Advanc **6** (12): 1249-1255

Htet MN, Soomro NS, Jiang Bo H 2016: Effect of Intercropping of maize (*Zea mays* L.) and soybean (*Glycine max* L.) on green forage yield and quality evaluation. IOSR J Agric Vet Sci (IOSR-JAVS) **9** (12): 59-63

Javamard MN., Javanshir A, Moghaddam M, Janmohammadi H 2009: Forage Yield and Quality in Intercropping of Maize with Different Legumes as Double-Cropped. J Food Agric Envir **7**: 163-166

Kipkemoi PL., Wasike VW., Ooro PA, Riungu TC, Bor PK, Rogocho L 2010: Effects of Intercropping Pattern on Soybean and Corn Yield in Central Rift Valley of Kenya 1478-1484

Khan A, Bari A, Khan S, Hussain NS, Zada I 2010: Performance of cowpea genotypes at higher altitude of NWFP. Pakistan J Botany **42**: 2291
Lithourgidis AS, Vasilakoglou IB, Dhima KV, Dordas CA, Yiakoulaki MD 2006: Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crops Res **99** (2): 106-113
Mugweni BZ, Titterton M, Maasdorp BV, Gandiya AF 2000: Effect of Mixed Cereal Legume Silages on Milk Production from Lactating Holstein Dairy cows (R7010). 3rd Workshop Livest. Prod. Prog. Projects, Matobo, Zimbabwe 82-89
Ofori F, Stern WR 1987: Cereal-Legume Intercropping Systems. Advanced Agronomy **41**: 41-90. DOI: https://doi.org/10.1016/S0065-2113(08)60802-0
Prasad RB, Brook RM 2005: Effect of Varying Corn Densities on Intercropped Corn and Soybean in Nepal. Exper Agric **41**: 365-382
DOI: https://doi.org/10.1017/S0014479705002693
Putnam DH, Herbert S, Vargas J 1985: Intercropping Maize-soybean studies, yield composition and protein. J Experimental Agric **22**: 375-381
Statistical Analysis System SAS. 2002: User's Guide: Statistics, Version 8.02. SAS Institute Inc. Cary, USA
Stoltz E, Nadeau E, Wallenhammar AC 2013: Intercropping maize and fababean for silage under Swedish climate conditions. Agric Res **2** (1): 90-97
Vasilakoglou, I, Dhima, K, Lithourgidis, A, Eleftherohorinos, I 2008: Competitive ability of winter cereal-common vetch intercrops against sterile oat. Experim Agric **44**: 509-520
Van Soest, PJ, Robertson, JB, Lewis, BA 1991: Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci **74**: 3583-3597
Zhu Y, Bai CS, Guo XS, Xue YL, Ataku K 2011: Nutritive Value of Corn Silage in Mixture with Vine Peas. Anim Production Sci **51**: 1117-1122