Yield and nutrient uptake of white cabbage affected by different intercrops

Martina BAVEC1, Bojana BROZOVIĆ2, Silva GROBELNIK MLAKAR1, Martina ROBAČER1, Manfred JAKOP1, Franc BAVEC1

1University of Maribor, Faculty of Agriculture and Life Sciences, Pivola 10, 2311 Hoče, Slovenia, (e-mail: martina.bavec@uni-mb.si)

Abstract
Intercropping represents an important production method in organic farming, contributing to its sustainability and productivity. The present trial was conducted to determine the effects of different intercropping systems on yield and mineral content of cabbage (Brassica oleracea L. var. capitata f. alba DC) in organic farming. It was performed under the field conditions in 2008 and 2009. Cos lettuce, bush bean, celery, tomatoes, red beet and leek were used as intercrops. Results showed that significant effects of intercropping systems on yield, dry matter and the nutrition uptake of cabbage were present, although, the cabbage in pure stand in general demonstrated better results.

Key words: mixed cropping, organic farming, mineral content

Introduction
Organic vegetable production is recognized as environmentally friendly production and is becoming more important also due to increasing demand among consumers. Good and quality yield performance often includes production systems providing stable agricultural conditions. Intercropping has been reported as the most suitable approach to provide the sustainability of vegetable production (Coolman and Hoyt, 1993), enhance yield and yield stability (Willey, 1979), increase resource use efficiency, especially of nitrogen (Jensen, 1996), reduce weed infestation (Hauggaard-Nielsen et al., 2001) and the occurrence of plant diseases and pests (Altieri, 1999). Cabbage is not a space efficient crop; however, it is a relatively long season crop, growing slowly at early growth stages, which opens an opportunity for other vegetables to be grown between the rows (Fukai and Trenbath, 1993). The advantages of vegetable intercropping, which could lead to better land use efficiency as an important component of organic farming, have been demonstrated by Guvenc and Yilidirim (1999). Many other studies indicate that intercropping with different vegetables is more productive and profitable than sole cropping (Yildrim and Guvenc, 2005; Žuljan et al., 2008; Bavec et al., 2010). In addition, mixed stands have often more efficient mineral uptake and utilization compared to sole cropping (Wooley and Davis, 1991; Morris and Garrity, 1993). Despite literature cited in the present study, there is a lack of data on yield performance and nutrient uptake of mentioned vegetable mixtures in organic agriculture. The aim of this study is to investigate organic cabbage production in intercropping based on yields and nutrient uptake.

Materials and methods
The present study was conducted under the field conditions at the University Agricultural Centre Pohorski Dvor in Pivola near Maribor, Slovenia, and managed according to organic farming rules (EC 834, 2007 and EC 889, 2008), in 2008 and 2009. The mean air temperature of the area in the growing period (May-September) was 18.6 ºC in 2008 and 19.8 ºC in 2009, while total rainfall in the same period amounted to 436 mm in 2008 and 809 in 2009. Soil chemical characteristics were in 2008 and 2009 as following: pHKCl 6.0 and 6.1, AL P2O5 23.1 and 29.5 mg 100 g-1soil, AL K2O 16.5 and 12.7 mg 100 g-1soil and Nmin 25.3 and 27.6 kg ha-1.
The experiment was performed in thirteen treatments as randomized block design with four replications on district cambisol, each with basic plot size 4.5 × 3.6 m. Cabbage (Brassica oleracea L. var. capitata f. alba DC) as the main crop was intercropped with cos lettuce (Lactuca sativa L. var. capitata DC), bush bean (Phaseolus vulgaris L. var. communis), celery (Apium graveolens L.), tomatoes (Lycopersicum esculentum Mill.), red beet (Beta vulgaris L. ssp. rubra L.) and leek (Allium porrum L.). All crops were also grown in pure stands (not presented in this paper). Cabbage spacing in sole cropping as well as in intercropping was 75 × 60 cm. In intercropping treatments, plants were planted between cabbage rows with usually plant density. Cabbage, cos lettuce, tomatoes, leek and celery were transplanted on May 7 and 8, 2008 and May 12 and 13, 2009. Red beet and bush bean were field-seeded on the same time. Fertilisation was preformed equally for all treatments in both years, according to the recommendations for integrated cabbage production (N_{min} target value 240 kg N ha^{-1}, 65 kg P_{2}O_{5} ha^{-1} and 280 kg K_{2}O ha^{-1}). The applied fertilizers were oil pumpkin cakes (9.6% N, 0.21% CaO, 0.5% P_{2}O_{5} and 0.82% MgO), potassium salt (40% K_{2}O) and crude phosphate (32% P_{2}O_{5}). Weeds were controlled manually in both years. The tested crops were harvested when they reached marketable size and quality and cabbage heads were placed in nylon mesh bags and stored in optimal conditions until analyses took place. After harvest, cabbage head weight and yield were measured, with all the measurements made by taking 10 plants from the centre of each plot. Nitrate was extracted from the fresh cabbage sample with H_{2}O and determined spectrophotometrically according to EN 12014-7 (1998). Chemical analyses were performed for fresh (not presented here) and dried samples. Total nitrogen was determined by the micro-Kjeldahl method. Plant samples were dried at 60 ºC, crushed and wet-fired with nitric-perchloric acid. Macro- and micro- nutrients (N, P, K, Ca, Mg and Fe) were determined according to ISO 6491 (1998) and ISO 6869 (2000). Data were evaluated by analysis of variance using the Statgraphics Centurion XV statistical program (Statgraphic®, 2005) with the significance level set at P ≤ 0.05. The comparison of means was done by the Duncan test (α=0.05).

Results and discussion

The highest cabbage yield (66.04 t ha^{-1}) was achieved in pure stand (Table 1); however, it was not significantly different from the yields achieved in treatments with cos lettuce and red beet. Results confirm the findings of Bavec et al., (2010) in the same intercropping system and Gliessman (1998) in the brocoli:lettuce intercropping system. In comparison to pure cabbage stands, the yields of cabbage intercropped with bush bean and tomatoes were significantly lower. Results were in contrast to Guvenc and Yildirim (2006), who reported no significant differences among the cropping systems in terms of cabbage yield, where cabbage was intercropped with bean, but results confirm findings of Bavec et al., (2010). The obtained results also differ to Poniedzialek and Kunicki (1995) in the case of the cabbage:bean treatment and Subhan (1991) in the case of the tomato:bean treatment. The cabbage yield response was also lower at treatments with celery and leek. Compared to sole crop, (relative yield = 1.00), lower relative yields were obtained when cabbage was intercropped, which proves that a competitive mechanism acted between the cabbage and other intercrops. Years had no effect on cabbage yield and the year x treatment interaction was significantly, contrary to DM (dry matter) content. The average DM content of cabbage leaves was higher in 2009 than 2008. The DM contents of cabbage intercropped with bush bean, celery, tomatoes and leek were significantly lower compared to the pure cabbage treatment; however, the obtained value on pure cabbage treatment was similar to treatments where cabbage was intercropped with red beet and cos lettuce. The highest N uptake was analysed in the cabbage pure stand treatment, in contrast to Varghese (2000) and Santos et al. (2002), who reported no significant response of N uptake in cabbage to various intercropping systems.

The results of N uptake obtained in the pure cabbage treatment were similar to the cabbage:cos lettuce treatment, but higher than in treatments with other intercrops. The influence of a specific year was very significant looking at NO_{3}^{-} concentration. In 2009, the concentration of NO_{3}^{-} was almost three times lower than in 2008. This was most likely the result of the high amount of rainfall in the growing period of 2009 (809 mm), which caused NO_{3}^{-} leaching. Pure cabbage and the cabbage:cos lettuce intercrops had the highest NO_{3}^{-} concentration. The treatments with celery, tomatoes and leek had lower NO_{3}^{-} contentation compared to those mentioned above. The lowest NO_{3}^{-} concentration was measured on cabbage:red beet treatment. The uptakes of Ca, Mg, K, P and Fe in leaves from the pure cabbage treatment were different compared to intercropped cabbage, resulting in higher uptake of all minerals (Table 2). This is contrary to Varghese report (2000), who indicated that intercropping with six different vegetables did not affect the N, P and K...
uptakes of intercropped cabbage compared to pure cabbage. In addition, Santos et al. (2002) reported that the uptakes of N, P, K and Ca in leaves of intercropped vegetables were similar to those from sole cropping. In the present study, the lowest uptakes of Ca, K and P were detected in treatments where cabbage was intercropped with bush bean, celery and tomatoes. These uptakes were significantly different compared to pure cabbage cropping, but without differences among them. The Mg uptake measured in leaves of cabbage as a pure stand was higher than in intercropped cabbage, while the same was not affected by intercrops. The highest Fe uptake was obtained on pure stand cabbage, but not statistically different compared with cabbage:red beet treatment whereas other intercropped treatments recorded statistically different and lower results compared to those mentioned above. Year significantly influenced Ca, Mg and Fe uptakes, but not K and P.

### Table 1. Yield (t ha⁻¹), relative yield (RY) and dry matter (DM, t ha⁻¹) content; nitrogen (N, kg ha⁻¹) uptake and nitrate (NO₃⁻, mg kg⁻¹) concentration of cabbage in relation to year and various cabbage-based intercropping systems

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield</th>
<th>RY</th>
<th>DM</th>
<th>N</th>
<th>NO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>55.78 a</td>
<td>3.93 b</td>
<td>116.85 a</td>
<td>788</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>51.87 a</td>
<td>4.50 a</td>
<td>97.22 b</td>
<td>339</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Nutrient uptake by cabbage (kg ha⁻¹) in relation to year and various cabbage-based intercropping systems

<table>
<thead>
<tr>
<th>Year</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>P</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>28.70 a</td>
<td>5.60 b</td>
<td>124.56 a</td>
<td>16.71 a</td>
<td>0.20 a</td>
</tr>
<tr>
<td>2009</td>
<td>24.89 b</td>
<td>6.35 a</td>
<td>130.61 a</td>
<td>15.86 bc</td>
<td>0.17 b</td>
</tr>
</tbody>
</table>

### Conclusions

The present study showed that cabbage sown in pure stand had the highest yield, relative yield, dry matter and nutrient uptake compared to other treatments. Intercropping systems resulted with similar but still lower results of all measured parameters with the exception of the cabbage:cos lettuce treatment. The lowest and statistically different results for all measured parameters, compared to the pure stand cabbage, were obtained in the intercropping systems with bush bean, celery and tomatoes. The obtained differences
regarding yield, DM and N, P and K uptakes in relation to the pure stand cabbage and the cabbage intercropped with cos lettuce were not statistically proven. The decrease of nutrient uptake in intercropped cabbage indicated that competition for macronutrients and Fe between species existed. Year did not affect yield and K and P uptakes in cabbage; however, the year treatment interaction was present, including yield and nutrients with the exception of P and DM. Climatic conditions in 2008 resulted in the higher average results of observed parameters, while DM and Mg uptake were higher in 2009.

Acknowledgements

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