COMPETITIVE ABILITY OF MAIZE IN MIXTURE WITH CLIMBING BEAN IN ORGANIC FARMING

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Abstract

Intercropped crops represent an important production system in organic farming, especially maize/climbing bean mixture due to its high content of protein in bean seeds for human diet, and producing silage for ruminants. To test this hypothesis, the effects of maize (*Zea mays* L.) sown as a sole crop and maize/climbing bean (*Phaseolus vulgaris* L. cv. Cipro) mixtures on maize plant height, maize leaf area index, bean leaf area index and grain yield were investigated in field experiments on an organic farm following accepted rules of certification. The maize/climbing bean mixture increased maize plant height as well as maize and bean leaf area and reduced maize grain yield in comparison with maize sown as sole crop, but 477.5 kg ha^{-1}seed yield of bean sown in mixture was obtained. Maize was a stronger competitor than bean. The overall conclusion is that maize/bean mixture has promise for producing valuable yield of maize and bean, but mixtures needs further investigation.

Introduction

In organic farming systems designed in accordance with EU regulation 2092/91, agricultural systems are often based on intercropped plants growing in plant mixtures, especially intercropped maize (*Zea mays* L.) and grain legumes. Most researches have been focused on bush bean ~~has~~ and maize planted simultaneously in alternate rows (Willey and Osiru, 1972; Francis et al., 1978; Santalla et al., 1995; Pilbeam, 1996; Santalla et al., 1999; Santalla *et al*., 2001;), but in Slovenia and other countries in addition to intercropped maize and climbing bean (*Phaseolus vulgaris* L.). Maize/bean intercropping may help converse a deficiency of bean production in European countries (Santalla et al., 1995), for example in organic farming where maize for grain produced for human consumption. Due to high crude protein value and increased nitrogen digestibility for ruminants compared to maize silage (Anil et al., 2000), maize/climbing bean silage may be an important source of proteins for ruminants. Important benefits in organic farming of intercropping cereals with legumes are as follows: efficient competition of cereals with weeds, improved soil structure, reduced loss of plant nutrients, less damage of plants to pathogens and insects (Herrmann, 1993), and more available nitrogen due to nitrogen fixation with legumes, with up to 84% of nitrogen may be derived from fixation by climbing bean (Kumarasinghe et al., 1992. For yield performance in plant mixtures, the Land Equivalent Ratio (LER: Mead and Willey, 1980) has been used to measure the agronomic advantage of the mixture, and the aggressivity (McGilchrist and Trenbath, 1971) used to identify dominant species or subordinate species in the mixture. Leaf area is measured (Tethio – Kagho and Gardner, 1988a,b; Bavec and Bavec, 2001, Bavec and Bavec, 2002) and has shown a strong correlation with yield. In spite of cited literature, the growth and yield performance of mentioned crop mixtures in organic farming have not been traced in literature. The aim of this report is to compare influences of intercropped system (maize/climbing bean and maize mixtures) with maize sown as sole crop on some morphological changes and grain yield production in organic farming. In accordance with results we wish to initiate research for new production needs.

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Methodology

In Majšperk (organic farm Živec), Slovenia, in two years, maize (*Zea mays* L.) was grown as a sole crop, maize/climbing bean (*Phaseolus vulgaris* L.) mixture and system performance observed in the field experiment. Initial experiment was performed only in three treatments in a randomized block design with four replications. Plots were 4.0 x 5.6 m, with a constant 0.7 m inter-row spacing (common in maize production practise). The soil texture was loam. Characteristics of soil in 1997 and 1998 were: 5.4 and 5.7 pH (0.1 N KCl), 2.6 and 2.3% of organic carbon, 9.0 and 11.0 P_2O_5 mg 100 g^{-1} soil (ammonium lactate), 14.0 and 17.0 K_2O mg 100 g^{-1} soil (ammonium lactate), 139 and 159 kg ha^{-1} of mineral nitrogen (nitrate, ammonium), as measured in the soil layer from 0 to 0.9 m before maize sowing, respectively. Conventional tillage and fertilisation with stable manure (30 t ha^{-1}) and cover crop (*Phacelia tanacetifolia* Benth.) with 2 t dry matter ha^{-1} were applied. The land race maize 'dent type' genotype was sown on 27 and 29 April (first and second year, respectively), and on 16 and 17 May the indeterminate-type climbing bean cv. Cipro. On 4 and 6 June the plants were thinned to the final stand. Plant populations were 5.6 plants m^{-2} of maize and 12.0 plants m^{-2} of bean in intercropping and the same plant populations in sole cropping. Weed control was done manually, depending on weeds. Maize plant height to cob at the stage of flowering (Maier code 57; Schütte and Meier, 1981), and green leaf area index (LAI) of all species was measured at the maize waxy maturity stage (83), when the maize expressed the maximum value of LAI (Bavec, 2002). Ten maize plants and ten bean plants from inside the plots for each repetition were taken to evaluation. Individual green leaf areas were measured using scanner and personal computer, which enabled counting the number of black dots on the screen picture of leaves to determine the leaf area (Bavec and Bavec, 2002). On this basis LAI value (leaf area units per unit land area) were calculated. Yield harvest was on 2 and 3 October in first and second years. Ten plants per each plot were weighed after drying (two months field ear drying and then 1 day at 70^o C) and calculated as yield for silage kg ha^{-1}. The grain yield was determined by harvesting 10 m^{-2} area from middle rows in plot and inside plants in row (Davis et al., 1981) in each subplot and replication. After drying (70 ºC, two days) the maize grain yield was calculated to the content of 14% moisture, and bean seeds with 11% of moisture. The Land Equivalent Ratio for maize (LER: Mead and Willey, 1980) was used to measure the agronomic performance of the mixture, allowing comparison of grain yield of maize and climbing bean in mixture with maize sown as a sole crop. LER values >1.0 indicate an agronomic benefit of growing a mixture over sole crops, since the index denotes how much land would be required for growing sole crops to obtain the same yields of each component as was obtained in the mixture. The aggressivity (McGilchrist and Trenbath, 1971) of maize with respect to climbing bean is given by difference between grain yield of maize (mixture/sole crop) and the grain yield of bean (mixture/sole crop). LER values and aggressivity were calculated for mean grain yield of maize and maize/bean mixture. Analysis of variance (ANOVA) among years and treatments was conducted using SPSSX for factorial experiments and the significance of factor effects, determined at $P \leq 0.05$ (*). Significant differences in the mean values were determined using the Tukey test at significance level $P \leq 0.05$, where different letters indicate significantly different means. The correlation coefficients between grain yield and LAI were calculated.

Results and discussion

In the experimental site the total rainfall during the vegetative period (from May to September) was 565 mm in first year and 681 mm in second year (30 years average is 566 mm). During the vegetative period among monthly rainfall total there were no considerable deviations in comparison with the long term averages. In second year June, July and August were warmer (average were 19.9, 20.7, 20.8^o C, respectively) compared to first year (19.0, 19.9 and 19.8^o C, respectively), but May and September were warmer in first year (16.4 and 16.1^o C, respectively) than in second year (15.7 and 15.1^o C). With regard to climatic requirements of these crops, it appears that conditions were normal for growth and development. Interactions of year by treatments for the measured parameters were not significant.

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Plant heights of maize to cob were not significantly different between years and ranged from 1.38 to 1.40 m. Maize/climbing bean mixture had significantly influenced taller maize plants (1.41 m) in comparison with maize sown as sole crop (1.35 m). Maize plant height was not significantly affected by maize/bean mixture. LAI of maize varied between years from 3.6 to 4.1, but LAI of maize was not significantly different in all treatments. Total system LAI of maize-climbing bean mixture was significantly higher (5.0) than LAI of maize sown as sole crop (3.7). In average, LAI of maize in all treatments varied from 3.8 to 4.1, similar to LAIs in the same plant populations in conventional farming system (Tethio – Kagho and Gargdner, 1988a,b; Bavec and Bavec, 2001, Bavec and Bavec, 2002). Bean and maize grain yields were significant (*P = 0.05*) between years, but the trends of treatment effects on yield are similar in both years, thus years were combined and averages reported. Averaged over two years, maize grain yield was significantly lower in maize/climbing bean mixture (11.20 kg 10 m^{-2}) compared to maize sown as sole crop (12.07 kg 10 m^{-2}), (Fig.1), but mixture produced also additional 0.48 kg 10 m^{-2} grain yield of bean.

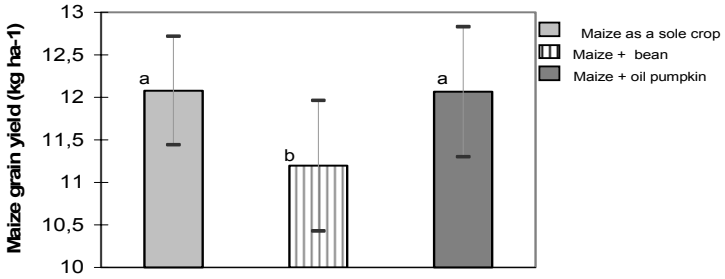

Fig. 1: Grain yield of maize as sole crop and intercropped (also with oil pumpkins)

At these experimental plants population before the ensiling process, similar trends were noted in plant dry matter production for total silage (maize sown as sole crop and maize/bean intercropping: 25.4 t and 24.5 t of silage ha^{-1}, respectively). Maize/bean mixture on the basis of our results produced high yield of mixed silage, the same as sole maize, but which could be an important source of protein from beans (grains of cv. Cipro content from 20.0 to 23.7% of crude proteins on dry weight basis) to improve ruminant nutrition (Anil et al., 2000). Mixture of maize with climbing bean is important in organic farming, similar to intercropped wheat and field beans (Bulson et al., 2000). Among LAI values in maize as sole crop and maize/bean mixture a positive correlation was calculated between LAI and grain yield (r = 0.98* and 0.95; r = 0.73 and 0.27, maize as sole crop and maize/bean mixture in 1997 and 1998, respectively). LER values for maize varied from 0.91 to 1.0 in 1997 and 1998 respectively, and averaged 0.98. LER $\leq$ 0.1 indicated a disadvantage due to intercropping. But LER varied between years in this trial (data not shown), and in other work similar maize LER values were found for maize and bush bean under long and short rains, and close to 1.0 in both seasons (Pilbeam et al., 1994). There could be an adventage to the intercropping due to higher silage value as economics of selling the two crops (data not shown). Aggressivity index data for maize with respect to climbing bean were positive in both years (0.49 in 1997 and 0.44 in 1998, respectively) and averaged 0.45. This showed that maize was the stronger competitor. As previously found in bush bean (Francis et al., 1982; Pilbeam et al., 1994) maize was more competitive than climbing bean in experimental conditions.

Conclusions

On the basis of research results the following may be concluded: maize/climbing bean mixture increases plant height of maize, increases the sum of maize and bean leaf area index and reduces maize grain yield in comparison with maize sown as a sole crop. Maize/bean mixture can compensate for lower grain yield of maize with higher bean yield, especially if more than 20% of crude protein content in dry bean seeds should taken into account. We can conclude, that this initial investigation show that results of maize/climbing bean mixture are promising, and for those reasons further research should be done.

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References

Anil, L., Park, J., Phipps, R. H. (2000) The potential of forage-maize intercrops in ruminant nutrition. Animal Feed Sci. Techn. 86, 157-164.

Bavec, F. (2000) *Oil pumpkins* (*Cucurbita pepo* L. convar. *giromantiina* var. *oleifera* Pietsch., Syn.convar. *citrullina* (L) Greb. var. *styriaca* Greb.). In: *Some of disregarded and /or new field crops*. University of Maribor, Faculty of Agriculture, pp. 21-27, (In Slovenian).

Bavec, F., Bavec, M. (2001) Effects of maize plant double row spacing on nutrient uptake, leaf area index and yield. Rost. Vyr. 47, 135-140.

Bavec, F. & Bavec, M. (2002) Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars (FAO 100-400). Eur. J. Agron. 16, 151-159.

Bavec, F., Gril, L., Grobelnik-Mlakar, S., Bavec, M. (2002) Seedlings as an alternative to direct sowing: yield and production costs. Bodenkultur 53, 29-33.

Bulson, H. A. J., Snaydon, R. W., Stopes C. E. (2000) Effects of plant density on intercropped wheat and field beans in an organic farming system. J. Agric. Sci. 1238, 59-71.

Davis, J. H. C., Amézquita, M. C., Muńoz, J. E. (1981) Border effects and optimum plot sizes for climbing beans (*Phaseolus vulgaris*) and maize in association and monoculture. Exp. Agric. 17, 127-135.

Francis, C. A., Prager, M., Tajeda, G. (1982) Effects of relative planting dates in bean (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) intercropping patterns. Field Crop Res. 5, 45-54.

Francis, C. A., Prager, M., Laing, D. R., Flor, C. A. (1978) Genotype x environment interactions in bush bean cultivars in monoculture and associated with maize. Crop Sci. 18, 237-242.

Hermann, G., Plakolm, G. (1993) Organic farming (Husbandry for practice), Verlagsunion Agrar, Vienna, Munich, Frankfurt, Munster-Hiltrup, Wabern-Bern, (In German).

Hillebrand, A., Murkovic, M., Winkler, J., Pfannhauser, W. (1996) Content of vitamin E and unsaturated aminoacids as a new breeding goals of pumpkins breeders. Ernährung, 20, 525-527, (In German).

Idouraine, A., Kohlhepp, E. A., Douraine, A., Kohlhepp, E. A., Weber, C. W., Warid, W. A., Martinez-Tellez, J. J. (1996) Nutrient constituents from eight lines of naked seed squash (*Cucurbita pepo* L.). J. Agric. Food Chem. 44, 721-724.

Kumarasinghe, K. S., Danso, S. K. A., Zapata, F. (1992) Field evaluation of N-2 fixation and N-partitioning in climbing bean (*Phaseolus vulgaris* L.) using N-15. Biol. Fert. Soils 13, 142-146.

McGilchrist, C. A., Trenbath, B. R. (1971) A revised analysis of plant competition experiments. Biometrics 35, 659-671.

Mead, R., Willey, R. W. (1980) The concept of a 'Land Equivalent Ratio' and advantages in yields from intercropping. Exp. Agric.16, 217-228.

Pilbeam, C. J., Okalebo, J. R., Simmonds, L. P., Gathua, K. W. (1994) Analysis of maize-common bean intercrops in semi-arid Kenya. J. Agric. Sci. 123, 191-198.

Pilbeam, C. J. (1996) Variation in harvest index of maize (*Zea mays*) and common bean (*Phaseolus vulgaris*) grown in a marginal rainfall area in Kenya. J. Agric. Sci. 126, 1-6.

Santalla, M., Deron, A. M., Casquero, P. A. (1995) Nutritional and culinary quality of bush bean populations intercropped with maize. Euphytica 84, 57-65.

Santalla, M., Casquero, P.A., de Ron, A. M. (1999) Yield and yield components from intercropping improved bush bean cultivars with maize. J. Agron. Crop Sci. 183, 263-269.

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