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CROP INTERACTIONS IN GREEN BEAN INTERCROPPING WITH LETTUCE AND RADISH

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Abstract

The scope of improving vegetable production through suitable intercrop combinations has not yet been exploited to its full potential. Research goals were to evaluate crop suitability for intercropping systems, to evaluate the effect of fertilization and sowing dates on productivity of green bean, lettuce and radish and to study the main factors responsible for crop performance when intercropped under field conditions in 2009–2010. A field trial was set up in a random block system with four repetitions on experimental field of the Institute for Vegetable Crops in Smederevska Palanka, Serbia. Green bean (*Phaseolus vulgaris* L.) as a main crop was intercropped with leaf lettuce (*Lactuca sativa* L.) and radish (*Raphanus sativus* var. *radicula* L.). Also, all crops were grown in pure stands. The intercrops were created according to the method of replacement series. The treatments of fertilization consisted of following variants: control treatment without fertilization, microbiological and mineral fertilizers and farm yard manure. All the treatments were examined for two sowing periods, spring and summer.Yield variation was significantly affected by the year of sowing, fertilization and interaction of these factors. LER values were always larger than 1 in intercropping systems. The mechanisms involved in the overyielding were the green bean canopy plasticity and its temporal deployment asynchrony when compared with lettuce and radish, allowing reduction of competition for light and production factors. The study showed that green bean based intercrops might provide the higher total yields.

Keywords*: intercropping, green bean, lettuce, radish, LER index*

Introduction

Intercropping is a traditional cultivation practice widely used all over the world (Carruthers et al., 2000; Ghosh et al., 2009). As a type of mixed cropping, it is defined as a cultivation of two or more crops in the same space at the same time (Vandermeer, 1989; Oljača et al., 2000 a).

Legume species are the most common members of intercrops, due to their ability to provide nitrogen through the sybiotic relationship with nitrogen-fixing bacteria. Comparing to corresponding sole crops, higher productivity was approved in many legume based intercrops, such as wheat and chickpea (Betencourt et al., 2012), barley and pea (Launay et al., 2009), maize and peanut (Xiong et al., 2013), maize and soybean (Dolijanović et al., 2013; Oljača et al., 2014) and especially maize and bean (Oljača et al., 2000 a; Mucheru-Muna et al., 2010; Worku 2014). The most of intercropping experiments were related to field crops. However there is lack of data for vegetable intercrops and only a few papers are strictly related to vegetable species (Yildirim and Guvenc 2005; Tosti and Thorup-Kristensen 2010).

Green bean (*Phaseolus vulgaris* L.) is very popular and widely grown vegetable species all over the world (Gepts 1998). As a member of *Fabaceae* family, green bean is in sybiotic relationship with nitrogen-fixing bacteria, and the majority of short green bean varieties mature after 50 to 60 days (Lešić et al., 2004). Lettuce and especially radish are also fast

ripening vegetable species (Lešić et al., 2004). During winter and spring, lettuce and radish are the first fresh vegetables on the market. Green bean, lettuce and radish are mentioned as good or bad neighbours in gardens (Lazić et al., 1991), but there is lack of data related to these intercrops analysed with contemporary scientific methods (Oljača et al., 2000b).
This study was conducted with a purpose to investigate the effects of intercropping green bean with lettuce and radish, different types of fertilizers and different sowing dates on green bean, lettuce and radish yields and productivity of intercrops evaluated using RY and LER indices.

Materials and methods

A two year (2009-2010) field experiment was conducted at the Institute for vegetable crops, Smederevska Palanka (44^o 22' N, 20^o 57'E, altitude 101 m above sea level), in order to evaluete vegetable intercropping systems based on green bean, lettuce and radish. Soil type was vertisol with pH 6.7, 3.13% of organic matter, 0.16% of nitrogen, 0.0% of calcium carbonate, 374.2 ppm of available phosphorus and 335.6 ppm available potasium (Egner et al. 1960).
The experiment was set up as a completely randomized block design with four replications. Lettuce (*Lactuca sativa* L. *cv.* "Neva") and radish (*Raphanus sativus* var. *radicula* L. *cv.* "Non plus ultra") were grown as a sole crops and intercropped with green bean (*Phaseolus vulgaris* L. *cv.* "Palanačka rana"). Green bean was also grown as a sole crop. Four fertilization treatments used were: a) control treatment without fertilization (C), b) microbiological fertilizer (MB), c) mineral fertilizer (NPK) and d) farm yard manure (FYM). All treatments were examined for two sowing periods, spring and summer.
The size of experimental plot was 12,5 m^2, with 0,5 m spacing between different experimental plots. Green bean sole crop experimental plots consisted of 12 rows (0.4 m inter-row spacing) and sowing density was 250 x 10^3 plants per hectare. Lettuce and radish sole crops experimental plots consisted of seedbeds, 1.0 m width, with 0.5 m spacing between seedbeds and sowing densities were 177x10^3 and 758x10^3 plants per hectar, respectively.
For intercropping treatments, the method of replacement series was used (de Wit 1960). Two rows of green bean (0.4) were associated with seedbed of lettuce or radish (0.8 m with). Plant spacing in mixtures was the same as in pure stands of examined crops. The number of plants per unit area in intercrops were 125 x 10^3, 114 x 10^3 and 525 x 10^3 plants per hectare of green bean, lettuce and radish, respectively.
Previous crop was wheat. The common tillage practices, such as plowing and disking were applied during the winter. Before additional tillage, certain experimental plots (fertilization treatments) were fertilized with mineral fertilizer (75 kg of nitrogen, phosphorus and potassium per hectare) or composted farmyard manure (40 t/hectare). Harrow with elastic spikes was used for presowing cultivation. Sowing (lettuce and radish: 13.04.2009. and 13.04.2010; green bean: 14.04.2009. and 16.04.2010.) and weeding were performed manualy.
Plots were watered several times during the growing season. With exception of certain plots mineral fertilizing, all cultivation measures were in accordance with organic production standards.
The microbial fertilizer Slavol (containing: *Bacillus megaterium, Bacillus licheniformis, Bacillus subtilis, Azotobacter chrocoocum, Azotobacter vinelandi, Derxia* sp.) was applied during the first true leaf stage of green beans. The application was performed using 1,5% microbial fertilizer aqueous solution in the amount of 6 l/ha. The treatment was repeated after 10 days.
At radish, lettuce and green bean maturity stage, iner rows were harvested and used to calculate yields per hectare, Relative yields (RY) and Land equivalent ratio (LER). LER is sum of the relative yields (RY) of intercrops (Vandermeer, 1989), green bean with lettuce

(LER = $RY_{green\ bean}$ + $RY_{lettuce}$) and green bean with radish (LER = $RY_{green\ bean}$ + RY_{radish}). The relative yields of green bean, lettuce and radish were calculated by following equation: RY = I / M (I is yield of some crop per hectare in intercrop and M is its yield per hectar in monoculture).

Results and discussion

Average monthly temperatures and rainfalls during the two experimental years, are shown in Figure 1. Comparing to long-term average, both experimental years were characterized by higher temperature values and rainfalls. In 2009 annual temperature mean (12,42^{o}C), and average monthly temperatures (except november) were significantly higher than long term temperature means for Smederevska Palanka. Annual rainfall sum was 788 mm, but in april and may, extreme drought, uncommon for spring time, was noticed. Another drought period with less rainfalls occured in august and september. In 2010, similarly as the previos year of trial, annual temperature mean (12,6^{o}C), and average monthly temperatures (except october and november) were significantly higher than long term temperature means. Despite the higher annual rainfall sum (730 mm), drought period appeared in august.

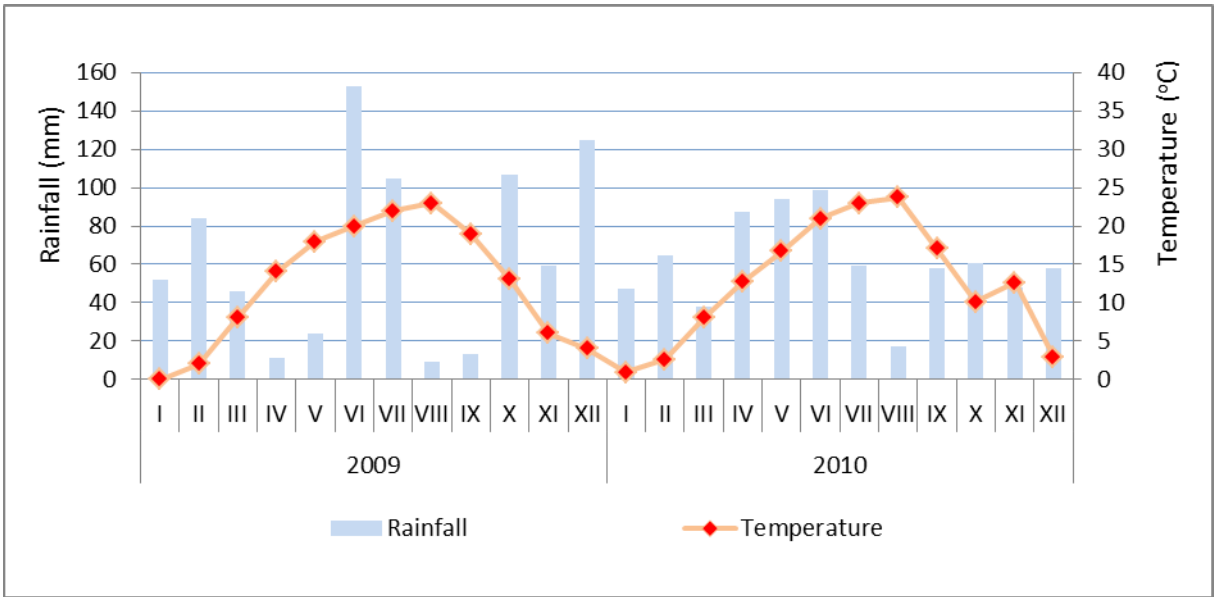

Figure 1. Average monthly temperatures (^{o}C) and monthly rainfall summs (mm) during the two experimental years (2009-2010)

Green bean, lettuce and radish yields were affected by tested fertilizers, as shown in Table 1. Comparing to control treatment, higher green bean, lettuce and radish yields were recorded on the plots treated with microbiological fertilizer and farmyard manure. Similar results were already reported for green bean (Stone et al., 2003) and lettuce yields (Okur et al., 2008). Radish yield was also affected by tested fertilizers but, in this trial it was lower than yield reported by Miladinović et al. (1997). The highest green bean, lettuce and radish yields were recorded on treatments with the mineral fertilizer, probably due to a high availability of major nutrients.

Table 1. Yields of sole crops (SC), relative yields (RY), standard errors (SE) and land equivalent ratio (LER) of intercropped (IC) green bean with lettuce and radish, treated with different fertilizers, during the two growing seasons (two years average: 2009-2010)

IC	Treatment	SC yield	SE	RY	SE	LER	SE

First sowing date (spring)							
Green bean Lettuce	Control	9,17 15,14	0,194 0,715	0,54 0,66	0,014 0,013	1,2	0,014
Green bean Lettuce	MB	10,04 17,84	0,149 1,158	0,52 0,65	0,01 0,008	1,17	0,014
Green bean Lettuce	NPK	10,47 20,53	0,132 0,812	0,53 0,67	0,006 0,008	1,2	0,005
Green bean Lettuce	FYM	9,92 17,94	0,197 0,77	0,52 0,65	0,012 0,01	1,17	0,018
Green bean Radish	Control	9,17 5,03	0,194 0,228	0,54 0,69	0,012 0,011	1,23	0,015
Green bean Radish	MB	10,04 5,45	0,149 0,265	0,51 0,69	0,009 0,009	1,2	0,01
Green bean Radish	NPK	10,47 5,86	0,132 0,119	0,51 0,69	0,008 0,004	1,2	0,008
Green bean Radish	FYM	9,92 5,66	0,197 0,19	0,5 0,71	0,017 0,017	1,21	0,031
Second sowing date (summer)							
Green bean Lettuce	Control	9,99 13,8*	0,154 0,215	0,49 0,66	0,013 0,01	1,16	0,014
Green bean Lettuce	MB	10,23 14,91*	0,093 0,522	0,51 0,66	0,009 0,009	1,17	0,004
Green bean Lettuce	NPK	11,33 16,45*	0,13 0,338	0,51 0,66	0,018 0,017	1,17	0,027
Green bean Lettuce	FYM	10,3 15,72*	0,236 0,495	0,51 0,69	0,015 0,012	1,2	0,027
Green bean Radish	Control	9,99 6,58*	0,154 0,311	0,5 0,71	0,014 0,008	1,21	0,017
Green bean Radish	MB	10,23 6,86*	0,093 0,107	0,48 0,71	0,013 0,011	1,19	0,009
Green bean Radish	NPK	11,33 7,33*	0,13 0,304	0,5 0,7	0,005 0,007	1,2	0,011
Green bean Radish	FYM	10,3 7,45*	0,236 0,231	0,52 0,72	0,019 0,006	1,25	0,016

Control – without fertilizer; MB – microbiological fertilizer; NPK – mineral fertilizer (15:15:15); FYM – highly decomposed farmyard manure; * - blossom emergence;

Subjected to the sowing season, green bean and radish yields were higher in the second sowing date but lettuce yields were higher in the first sowing date. That was not in accordance with results of Ferreira et al. (2006) who reported lower green bean yields in later sowing periods. Also, in second sowing period, green bean treated with FYM, achieved higher yields than those treated with microbiological fertilizer. It was presumably caused by better soil properties and water accumulation, improved with high amounts of organic matter, contained in FYM. However, in second sowing period, in lettuce and radish sole crops and intercrops, regardless to fertilizing treatments, frequent blossom emergence was noticed. High temperatures and long day terms could promote blossom emergence (Miladinović et al. 1997), so the lettuce and radish yield quality was significantly reduced.

Green bean relative yields (RY) varied about 0,5 in both intercrops, i.e. relative yields of green bean were not significantly affected by intercropping, regardless of another intercropped species. Slightly higher green bean RY values were recorded in the first sowing season but it is not definetly clear what caused these differences. Lettuce and radish RY were above 0,5 and influenced LER index values higher than one. LER is usually used for an intercrop efficacy evaluation. LER index higher than 1, sugests that the intercropping is much more efficient than sole crops and that the competition for light, water and soil resources among intercropped species is not significant (Vandermeer 1989).

Oppositly to first sowing period, in the second sowing period, LER index values of intercrops treated with FYM were higher than untreated or those treated with other fertilizers. It is probably corelated with soil water availability during the drought period. Hati et al. (2006) reported better rooting of soybean and improved physical properties of the soil after farmyard manure application.

Conclusion

Examined intercrops approved as a better choice, comparing to related sole crops. They could be useful in achieving higher total yields, regardless to applied fertilizer or sowing date. However different lettuce and radish genotypes should be used because the tested genotypes are not suitable for late season production. Application of microbiological fertilizers and highly decomposed farmyard manure are suitable for organic green bean/lettuce or green bean/radish intercropping production and also could lead to yield enhancing.

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