Josip Juraj Strossmayer University of Osijek
Faculty of Agrobiotechnical Sciences Osijek

56. HRVATSKI I 16. MEĐUNARODNI SIMPOZIJ AGRONOMA

56th CROATIAN AND 16th INTERNATIONAL SYMPOSIUM ON AGRICULTURE

5. – 10. rujna 2021. | Vodice | Hrvatska

September 5 – 10, 2021 | Vodice | Croatia

ZBORNIK RADOVA

PROCEEDINGS

Vodice, OLYMPIA Sky

Izdavač | Published by **Fakultet agrobiotehničkih znanosti Osijek**
Sveučilišta Josipa Jurja Strossmayera u Osijeku
Faculty of Agrobiotechnical Sciences Osijek
University Josip Juraj Strossmayer in Osijek

Za izdavača | Publisher **Krunoslav Zmaić**

Glavni urednici | Editors in Chief **Vlatka Rozman**
Zvonko Antunović

Oblikovanje | Design by **Ras Lužaić**

Tisak | Print by **VIN Grafika**

ISSN **2459-5543**

Fakultet agrobiotehničkih znanosti Osijek, Sveučilište Josipa Jurja Strossmayera u Osijeku
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Agronomski fakultet Sveučilišta u Zagrebu
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Veterinarski fakultet Sveučilišta u Zagrebu

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Ministarstva znanosti i obrazovanja Republike Hrvatske
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Ministarstva gospodarstva i održivog razvoja Republike Hrvatske

u suradnji s
Bc Institutom za oplemenjivanje i proizvodnju bilja, Zagreb
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Visokim gospodarskim učilištem u Križevcima
Vukovarsko-srijemskom županijom

organiziraju

56. hrvatski i 16. međunarodni simpozij agronoma

5. do 10. rujna 2021., Vodice, Hrvatska

ORGINAL SCIENTIFIC PAPER

Barley yield, yield components and nutrient content in intercropped system of walnut and barley

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Abstract

The aim of research was to determine the productivity of the intercropped system of walnut and winter barley and investigate how barley performed in that system in terms of yield, yield components, and nutrient content in the grain. Field trial consisted of three plots: a) control plot of monoculture barley; b) sole walnut orchard; c) walnut orchard with intercropped barley. Despite decreased barley yield, the LER value of 1.53 showed that intercropping had a productive advantage over monoculture systems. Also, the number of fertile spikelets, the length of spikes, the weight of 1000 grains, and the nutrients content of N, P, K, Cu, Fe, and Zn were statistically higher in barley grown in the intercropped orchard. These results suggest that walnut tree vicinity could have a positive effect on barley yield quality.

Keywords: intercropping, walnut, barley, productivity, nutrients

Introduction

In the last few decades, intercropping arable crops with wood species is showing to be potentially the most sustainable alternative to conventional agriculture production, as it provides many ecological benefits (Tsonkova et al., 2012). Besides ecological benefits, the addition of trees to arable systems can have a positive effect on intercrops by creating microclimate conditions that improve plant resistance to stress conditions (Gosme et al., 2016). It also provides protection against plant diseases, pests, and weeds (Pumari et al., 2015), and it can positively influence soil fertility (Zake et al., 2015), as well as water and nutrients availability (Zhu et al., 2020).

Barley is a widely adapted crop that grows under a wider range of environmental conditions than any other cereal, with winter barley cultivated mostly under warmer climatic conditions and summer barley in cooler climates. Approximately 65% of barley crop is being utilized as animal feed, around 30% for malting and brewing, and only 2–3% for human consumption, but that number is slowly increasing as its health benefits are becoming more recognized (Aldughpassi et al., 2015). Although the trend of declining areas sown with barley has been recorded for the past 15 years, it is still one of the most important agricultural crops in Croatia and ranks 3rd in terms of production (Iljkić et al., 2019). According to the latest data from the Statistical yearbook from 2018, there was a total of 53950 ha of agricultural land under barley production with a total production of 260426 t, and the average yield was 4.8 t ha-1 (Statistical yearbook, 2018).

The aim of our study was to determine how winter barley reacts to intercropping with walnuts in terms of yield, yield components and the nutrients content in the grain. We also examined the overall productivity of intercropped system by calculating the Land equivalent ratio (LER).

Materials and methods

The field trial was set up in eastern Croatia, near city Đakovo, on a loam soil with the effective soil depth of 1500 mm. Walnut orchard cultivated there is 12 years old with 10 rows of grafted walnut trees and 8 m alleys between trees. Within first 5 rows of orchard, barley was sown in strips of 6 m width. Field trial consisted of three plots, all in close proximity, on the same soil type and under the same soil management: a) control plot of monoculture barley; b) sole walnut orchard; c) walnut orchard with intercropped barley. Climatic parameters were monitored during the vegetation period of barley. After the harvest, soil samples were collected and analyzed for each system. Yields were determined by harvesting barley from 1 m^2 area, separating and weighing the grain and calculating the grain weight per 1 ha area to obtain total yields in t ha^{-1}. From the same 1 m^2 frame number of plants were counted to express plant density in each system. Yield components, the number of sterile and fertile spikelets, the length of stem and spikes, and the weight of 1000 grains were also measured by sampling random barley plants for each system. Analyses of K, Cu, Fe, Mn and Zn content in barley grain were determined on atomic absorption spectrophotometer, P on inductively coupled plasma and N by using Kjeldahl digestion method.

From the crop and walnut fruit yields, land equivalent ratio (LER) was estimated (Eq 1. The land equivalent ratio is defined as the ratio of the area under monoculture production to the area under intercropping needed to give equal yields at the same management level (Ong and Kho, 2015). It is calculated as the ratio of tree yield from intercropped system to the tree monoculture yield plus the ratio of crop yield from the intercropped system to the crop monoculture yield, as shown:

Equation 1.

When LER ≤ 1, there is no agronomic advantage of intercropping over sole cropping, but when LER is >1, production in the intercropped system is higher than in the separate sole crops.

Statistical analysis of the obtained data was conducted in R software using Student T-test, One-way ANOVA and Tukey's honestly significant difference (HSD) post hoc test. Non-parametric alternative tests were applied where appropriate.

Results and discussion

Walnut fruit yield was determined for walnuts in green husk, as it was harvested and sold in such market form. Fruit yield in intercropped orchard was 2136 kg ha^{-1} and in sole orchard 2625 kg ha^{-1}. Lower walnut yield in the intercropped orchard was expected since that area of the orchard consistently had lower yield for years, even before intercropping arable crops in the alleys between trees. Barley yield in monoculture plot was 7.52 t ha^{-1} and in intercropped orchard 7.21 t ha^{-1}. However, since only 75% (6 m out of 8 m) of the area in the intercropped orchard was covered with barley (the rest 25% was walnut rows), the actual barley yield per ha in the intercropped system was 5.41 t ha^{-1}. The sum of relative intercropped yields for walnut and barley gave an LER value of 1.53 (Eq. 2), which means that intercropping arable crops in walnut orchard increased productivity of that area by 53% in regards to monoculture systems.

Equation 2.

Significantly lower barley yield in the intercropped system is in accordance with significantly lower plant density in that system compared to monoculture plot (Table 2). Lower plant density and lower crop yields in intercropped systems are probably the result of shading from tree canopies, which showed to be determining factor in these systems (Dufour et al., 2013). In favor of the argument that the shading effect was the main factor reducing barley yield are generally better soil properties in the intercropped system than barley monoculture plot (Table 1).

Table 1. Soil parameters in three observed systems

	Monoculture barley	Intercropped system	Walnut orchard
pH *(H_2O)*	5.41 ^{b}	6.29 ^{a}	6.16 ^{a}
SOM *(%)*	1.54 ^{b}	1.96 ^{a}	2.20 ^{a}
AL-P_2O_5 *(mg/100g)*	7.49 ^{ns}	7.49 ^{ns}	7.28 ^{ns}
AL-K_2O *(mg/100g)*	10.56 ^{b}	12.37 ^{b}	20.51 ^{a}

^{ns} indicates no significant differences, ^{a} and ^{b} indicate significant difference (alpha=0.05), SOM – soil organic matter

Even though the total barley yield and plant density were reduced in intercropped system, all of the market-relevant yield components: the number of fertile spikelets, the length of spikes, and the weight of 1000 grains were significantly higher in the intercropped orchard (Table 2). Nutrient content analysis of barley grain also showed statistically significant differences in favor of intercropping for all observed elements, except Mn, which was significantly higher in barley grain grown in monoculture plot (Table 2).

Table 2. Yield, yield components and nutrient content in grain of barley in monoculture system and intercropped system

	Monoculture barley	Intercropped system
Yield *($t\ ha^{-1}$)*	7.52 ^{a}	5.41 ^{b}
Plant density *(plants per m^2)*	784 ^{a}	681 ^{b}
Number of fertile spikelets *(per plant)*	19.75 ^{b}	20.83 ^{a}
Number of sterile spikelets *(per plant)*	1.90 ^{ns}	1.76 ^{ns}
1000 grains weight *(g)*	54.17 ^{b}	64.00 ^{a}
Stem length *(cm)*	60.07 ^{ns}	60.74 ^{ns}
Spike length *(cm)*	6.81 ^{b}	7.62 ^{a}
N *(%)*	0.72 ^{b}	1.06 ^{a}
P *($mg\ kg^{-1}$)*	2636.6 ^{b}	3318.8 ^{a}
K *($mg\ kg^{-1}$)*	4487.2 ^{b}	5395.3 ^{a}
Cu *($mg\ kg^{-1}$)*	3.03 ^{b}	4.44 ^{a}
Fe *($mg\ kg^{-1}$)*	31.28 ^{b}	41.96 ^{a}
Mn *($mg\ kg^{-1}$)*	10.39 ^{a}	9.33 ^{b}
Zn *($mg\ kg^{-1}$)*	20.31 ^{b}	27.16 ^{a}

^{ns} indicates no significant differences, ^{a} and ^{b} indicate significant difference (alpha=0.05)

Although soil in intercropped orchard had more favorable properties in terms of pH and SOM, these observations (Table 2) could be attributed to the possible positive effect of walnut root net in nutrient acquisition from deeper layers of soil. Namely, in intercropped systems, tree roots can form horizontal net under crop root zone where this may act as safety-net intercepting mineral nutrients leaching from the topsoil. Also, associated with the safety net process is nutrient pumping - the acquisition of nutrients deeper in the soil profile by tree roots, the translocation of nutrients to litter tissue, the deposition of litter on the soil surface via litterfall, and the addition of nutrients to the top soil via decomposition processes (Isaac and Borden, 2019). These processes can positively affect soil fertility and thus increase the availability of nutrients to intercrops. Factors that could also have positive effect on yield components and nutrient uptake are better water utilization in the intercropped orchard (Droppelmann et al., 2000), as well as potentially greater root colonization by mycorrhizal fungi (Shukla et al., 2009).

Conclusion

Although barley yield was reduced in the intercropped orchard, the system had LER value of 1.53 meaning that intercropping had the advantage over sole cropping, i.e. increased productivity. Intercropping positively affected yield components; the number of fertile spikelets, the length of spikes, and the weight of 1000 grains were significantly higher than in the monoculture plot. Analysis of barley grain nutrient content also showed an advantage for intercropped systems, with statistically significant higher values than in barley grain from monoculture plot. Similar positive effects of tree vicinity on intercrops have been recorded before, but to fully evaluate belowground interactions between barley and walnut, a detailed assessment of roots and nutrients distribution in the soil is needed, as well as the assessment of water movement in such systems.

Acknowledgment

Authors would like to thank Croatian Science Foundation for funding this research through project UIP-7103 "*Intercropping of wood species and agricultural crops as an innovative approach in agroecosystems*"

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Prinos ječma, komponente prinosa i sadržaj hranjivih elemenata u konsocijacijskom sustavu oraha i ječma

Sažetak

Cilj istraživanja bio je odrediti produktivnost konsocijacijskog sustava oraha i ozimog ječma, kao i utjecaj ovakvog sustava na prinos ječma, komponente prinosa i sadržaj hranjivih elemenata u zrnu. Poljski pokus sastojao se od tri tretmana: a) kontrolna parcela ječma; b) voćnjak oraha; c) konsocijacija oraha i ječma. Iako je prinos ječma bio značajno smanjen, LER vrijednost od 1,53 pokazala je da je konsocijacijski sustav ostvario veću produktivnost nego konvencionalni sustavi. Također, broj fertilnih klasića, duljina klasa, masa 1000 zrna te sadržaj elemenata N, P, K, Cu, Fe i Zn bili su statistički značajno veći kod ječma uzgojenog u konsocijaciji. Ovi rezultati sugeriraju da blizina stabala oraha može imati pozitivan utjecaj na kvalitetu zrna ozimog ječma.

Ključne riječi: konsocijacija, orah, ječam, produktivnost, hranjivi elementi