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Crop management systems and endomycorrhiza effects on endive (*Cichorium endivia* L.) growth

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ABSTRACT

The goal of this research was to determine the influence of crop management systems, (organic, sustainable and conventional) and endomycorrhiza on vegetative growth of endive (*Cichorium endivia* L.) grown on fields in order to use PE mulch after lettuce crop. During 2002 and 2003 a two-factor trial with three repetitions and split-plot design was set up in Pula (Croatia). Main factor "crop management" had three levels (organic, sustainable and conventional); while the sub factor "mycorrhiza" had two levels (endive seedlings inoculated with endomycorrhizal fungus and non-inoculated seedlings). Endive was planted after lettuce harvesting on the set PE mulch in conventional and integrated management, while in organic management it was planted after tilling lettuce rests and plant mulch (fodder pea and common vetch). Fertilization (by fertirigation) and crop protection were performed according to basic principles of organic, sustainable and conventional crop management system. Neither mycorrhiza nor production systems had no significant influence on plant density, diameter and mass of heads, and marketable yields. The biggest endive head diameter had non-inoculated endive plants in first year of research, while in the second year this feature was not significant. Production system had no significant influence on head diameter. The sustainable production system had the most marketable endive heads, while the organic system had most non-marketable heads in the first research year, while in the second this feature was not significant. Mycorrhiza had no influence on this feature.

Key words: conventional production, endive (*Cichorium endivia* L.), endomycorrhiza, organic production, sustainable production

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IZVLEČEK

VPLIV NAČINA GOJENJA IN ENDOMIKORIZE NA RAST ENDIVIJE (*Cichorium endivia* L.)

Cilj raziskave je bil primerjati vplive ekološkega, integriranega in konvencionalnega gojenja endivije (*Cichorium endivia* L.) ter vpliv endomikorize na njeno rast. Endivija je bila gojena na PE zastirki kot naknadni posevek po solati. V letih 2002 in 2003 je bil dvofaktorski poskus v treh ponovitvah s split-plot zasnovo postavljen v Pulju (Hrvaška). Glavni dejavnik "način gojenja" je vseboval tri ravni (ekološki, integrirani in konvencionalni način), medtem ko je drugi dejavnik imal dve ravni (sadike endivije, inokulirane z endomikorizno glivo, in sadike brez inokuluma). Endivija je bila posajena po pobiranju solate na PE zastirko v konvencionalni in integrirani proizvodnji, medtem ko je bila v ekološki proizvodnji posajena po zaoravanju ostankov solate in rastlinske zastirke (krmni grah in navadna grašica). Gnojenje (fertiirigacija) in varstvo pred boleznimi ter škodljivci so temeljili na priporočenih metodah za ekološko integrirano in konvencionalno gojenje. Mikoriza in način gnojenja nista značilno vplivala na gostoto rastlin, premer in težo glav ter tržni pridelek. Največji premer glav so imele rastline, gojene brez inokuluma, v prvem letu raziskave, medtem ko v drugem letu med rastlinami ni bilo značilnih razlik. Način gojenja ni vplival na premer glav. Največje število tržnih glav je bilo v prvem letu doseženih v integriranem načinu, medtem ko je ekološki način dal največje število netržnih glav. Drugo leto poskusa se ta lastnost ni značilno pokazala na rastlinah. Prav tako tudi mikoriza ni vplivala na to lastnost.

Ključne besede: endivija (*Cichorium endivia* L.), ekološka pridelava, endomikoriza, konvencionalna pridelava, integrirana pridelava

INTRODUCTION

The conventional production systems from which most of vegetables originate is produced by high levels of chemization on specialized farms with high production and high inputs of materials and costs by which high yields are obtained and costs are lower per unit of production (Abdul-Baki, 1998; Shennan, 1992). Such production requires production procedures risky for the environment and people's health what leads to soil erosion and permanent soil degrading (Teasdale and Colacicco, 1985; Bašić, 1996). Also this type of conventional production requires use of polyethylene (PE) mulch which is used for many vegetable varieties which are grown from transplants (Abdul-Baki et al., 1992; Brown et al., 1992; Wien et al., 1993; Borošić et al., 1997; 1998; Romić and Borošić, 1998; Abdul-Baki, 1998; Ban et al., 2003; 2004.). Beside main positive influence that this mulch has in preventing weed growth, rising or reducing soil temperature (depending on colour), preventing disease spreading and finally improving yield quantity, these mulches are present as an ecological problem. On 87% of land in USA non degradable black polyethylene film has been used which causes additional costs for production (costs of purchase, setting up and removing the polyethylene film) and an ecological and environmental problem because it can be used only once and the question is how to recycle and waste it (Hemphill, 1993; Roe et al., 1994). Furthermore, in conventional production large amounts of fertilizers are used, especially nitrogenous ones. The reason is that nitrogenous fertilizers are a base for high yields but they are used several times more than the agricultural cultures need. The surpluses of nitrates are easily washed out of the soil, polluting the surface and ground waters (Romić et al., 1996; Abdul-Baki, 1998). In the same time too much nitrogenous fertilizer causes accumulation of unwanted nitrates in vegetables what affects human health (Ćustić, 1996).

Pesticides are used several times in conventional production even when there are no circumstances for disease or pest development, in order to prevent diseases and pest assuring the maximum possible yield what is unacceptable for ecology (Elliot and Mumford, 2002).

Recent research (Gaskell et al., 2000; Ban, 2001; Bulluck et al., 2002; Elliot and Mumford, 2002) showed possibilities of vegetable production in alternative systems of production (sustainable and organic), which are not so risky for the environment and create positive economic effects. Therefore the aim of our research was to show similar results of alternative systems of production (sustainable and organic) and influence of endomycorrhiza on vegetative growth and yields of endive (*Cichorium endivia* L.) as a late crop after lettuce, using the existing mulch, and comparing alternative to conventional systems of production.

MATERIAL AND METHODS

Biannual research was set on a family farm in Pula (Croatia) during 2002 and 2003. A two factor trial was set by split-plot scheme in three repetitions. The main factor “production system” had three levels (organic, sustainable and conventional); while the sub factor “mycorrhiza” had two levels (endive transplants inoculated with endomycorrhiza fungus *Glomus mossae* and non-inoculated transplants). The size of basic plot for the main factor “production system” was 45 m^2 (10 m x 4.5 m) contained three beds 1 m wide with 50 cm space between beds and were 10 m long, while the size of plots with factor “mycorrhiza” was 22.5 m^2 (5 m x 4.5 m), half of the plots of main factor.

The soil for the trial had neutral reaction (pH 7.07 in MKCl), contained 2.3% humus, 3.49 mg/100 g soil P_2O_5 and 17.95 mg/100 g soil K_2O. The trial land surface was ploughed 30 cm deep in February, each year. Before ploughing, on plots which are labelled for organic system of production, ripe organic manure was used (100 m^3/ha) and ploughed in the soil. On organic production plots, after supplementary treatment, tilling, in mid March we have sawn in the first year fodder pea variety ‘Maksimirski’, in the second year common vetch, variety ‘Jaga’, each 140 kg/ha. Both fodder pea and common vetch were mow down by end of May and were used as plant mulch for lettuce that forwarded endive.

In both years after mowing down the spring crop an drip irrigation system was set for organic production system, while for sustainable and conventional systems we used mineral fertilizers (1000 kg/ha NPK 7-20-30), and herbicide (trifluralin, 2 l/ha), we tilled, set drip irrigation systems and set mulch of black PE film 1.2 m wide. On such prepared plots in both years lettuce was grown (in beds) with 10.67 plants/m^2 on all trial plots. During vegetation in both years we used drip irrigation. Each year we used fertirigation, and basic measures of culture care depending on production system. Plant protection was done by State regulations: Rulebook on ecological production of plants and in total production of plant’s products (Official Gazette, 2001). Lettuce harvesting was done in third decade of August. After lettuce harvesting on plots with sustainable and conventional production systems, lettuce leftovers were removed, while on PE mulch holes for planting endive transplants were made. Lettuce leftovers and plant mulch (fodder pea and common vetch) in organic production were tilled in the soil.

Inoculation of endive with endomycorrhiza fungus was done by mixing the fungus mycelium in the substrate for transplants growing (Novak, 1997.). Transplants of variety ‘Laos’, Seed Company Bejo zaden were grown in a polyethylene container with 150 holes (sowing on 22. 7. 2002 and 18. 7. 2003). The transplants in phase 5-6 true leaves were planted in three bed rows per plot (in each bed we had three rows) on 4. 9. 2002 and 28. 8. 2003 the interspaced between rows was 30 cm and inside rows 50 cm (three rows per bed – mulch film), while the distance between beds was 50 cm (4 plant/m^2). For data processing we used data about the middle bed of each plots.

Before planting in planting holes on plots for sustainable and conventional production we used soil insecticide (Durban G-7.5) in amount of 15 kg/ha in sustainable and 20 kg/ha in conventional system. After planting on all plots we used molluscides against snails in dosage according to State regulations. In organic production we used mechanical protection and yellow tables to attract insects (aphids).

During vegetation we used irrigation according to vegetation needs, while fertilizer was applied by fertirigation (plots with organic production had no fertirigation), while treatments against diseases and pests were executed according to production system (Table 1 and 2).

Table 1: Fertilization regime in endive production systems

Fertilizer	Production system		
	Organic	Sustainable	Conventional
Soluble mineral fertilizer (NPK 19-6-20)	-	88 kg N/ha in two portions (every second week)	158 kg N/ha in four portions (every week)
Total kg N/ha	-	88	158

Endive harvesting was done at once on 8. 12. 2002 and 7. 12. 2003 on all plots and for all systems of production. After harvesting we determined the density of plants, the diameters of endive heads, average mass of endive heads yields and share of endive non-marketable yields.

Statistical analysis of the main factor, sub factor and their interaction was done by variance test (F-test). For significantly different average values of F-test between the main factor and its interaction, we tested them by Duncan's rang test for significance $p \leq 0.05$.

Table 2: Pesticide use in endive production systems

Pesticide	Production system		
	Organic	Sustainable	Conventional
Limacides: - Metaldehyde (Limax M)	1 x (30 kg/ha)	1 x (35 kg/ha)	1 x (40 kg/ha)
Insecticides: - Klorpirifos-etil (Dursban G-7.5) - Deltametrin (Rotor 1.25 EC) - Pyrethrum extract (Biotox P) - Yellow tables	- - 1 x (600 l/ha) 1.200 peace/ha	1 x (15 kg/ha) 1 x (0.06 %) - -	1 x (20 kg/ha) 2 x (0.06%) - -
Fungicides: - Metalaksil+mankozeb (Ridomil MZ 72 WP) - Iprodion (Rovral SC)	- -	- 1 x (0.30%)	1 x (0.30%) 2 x (0.30%)
Herbicides: - Glufosinat-amonij (Basta 15)	- (1 x weeding)	1 x (6 l/ha)	1 x (6 l/ha)

RESULTS AND DISCUSSION

Production systems, mycorrhiza and their interaction had no significant influence on density reduction in endive production during two years of research (Table 3). Snails are one of the reasons for diminished plant density, because they were very active starting in September, when more rains are usual in Pula. After transplanting the plant density was diminished by sun burns because of black mulch and sun influence. However in our research these causes were not to blame as we used molluscides in all three systems of production and the temperatures of soil in organic and on PE mulch surface in conventional and sustainable production system were not a limitation factor (data not shown). Insignificant diminished plant density in all three production systems in planting phase were caused by mechanical damage in time of planting.

The diameter of endive head is genetically determined feature that can be changed by wider planting spaces, but also is a feature that determines planting interspaces. In our research plants were planted on a distance that made full development possible. In all production years, mycorrhiza and interaction of mycorrhiza and production system had no influence on endive head diameter. These results are opposite to results (Ban et al., 2003) where lettuce heads were significantly larger in sustainable production, than in organic. The reason lies in the fact that endive has better tolerance and endurance to many stresses (weaker nutrition, water stress) than lettuce, therefore the production circumstances for endive with no manure, weeds and soil compression had not showed effects on head diameters. The differences were not significant either comparing organic to “softer” conditions of sustainable and conventional production. Inoculation of endive transplants with endomycorrhizal fungus has showed no significant results. We assume that was because soil available nutrients were sufficient to head development.

Table 3: Effects of production system and mycorrhiza on the achieved plant density and endive heads diameter in harvest time

Production system	Plant density (plant/m^2)			Diameter of heads (cm)		
	M[1]	BM[2]	PSP[3]	M	BM	PSP
	2002					
Organic	3.73 a	3.91 a	3.82 a	39.73 a	41.93 a	40.83 a
Sustainable	3.82 a	3.73 a	3.78 a	41.65 a	41.68 a	41.67 a
Conventional	3.73 a	3.47 a	3.60 a	40.07 a	40.50 a	40.29 a
Mean myc.	3.76 n.s.	3.70 n.s.		40.48 n.s.	41.37 n.s.	
	2003					
Organic	3.87 a	3.96 a	3.92 a	41.90 a	41.25 a	41.58 a
Sustainable	3.91 a	3.87 a	3.89 a	39.70 a	39.62 a	39.66 a
Conventional	3.96 a	3.91 a	3.94 a	41.82 a	41.55 a	41.69 a
Mean myc.	3.91 n.s.	3.91 n.s.		41.14 n.s.	40.81 n.s.	

[1]Mycorrhiza; [2]Without mycorrhiza; [3]Production system

The head mass was positively correlated to head diameter, larger diameters means in order bigger mass under the condition that endive is harvested in full technological ripeness, respectively when the inner parts have characteristic light yellow colour. Because of these reasons, in both years, endomycorrhiza and production systems had no influence on endive head mass (Table 4). These findings are contrary to the findings of Ban et al. (2003) in lettuce research. The reason is, as we mentioned before, that endive has higher tolerance than lettuce. Interaction of production system and mychorhizza was significant only in the second year of research, when the highest endive head mass was achieved in sustainable production system on non-inoculated transplants. This interaction was significant probably because pedological-climatic conditions were favourable for this interaction comparing to other interactions.

Table 4: Production system and mycorrhiza effects on average endive marketable yield and on proportions of non-marketable heads in yield

Production system	Marketable yield						Non-marketable yield		
	(g/head)			(t/ha)			(% heads)		
	M[1]	BM[2]	PSP[3]	M	BM	PSP	M	BM	PSP
	2002								
Organic	507 a	630 a	569 a	16.3 a	22.7 a	19.49 a	6.1 a	3.4 a	4.7 a
Sustainable	565 a	633 a	599 a	19.5 a	22.4 a	20.98 a	2.2 a	1.2 b	1.7 b
Convent.	491 a	474 a	483 a	17.1 a	15.0 a	16.05 a	3.1 a	2.5 a	2.8 ab
Mean myc.	521 n.s.	579 n.s.		17.6 n.s.	20.0 n.s.		3.8 n.s.	2.3 n.s.	
	2003								
Organic	653 ab	570 b	612 a	22.8 a	20.3 a	21.58 a	1.4 a	3.7 a	2.5 a
Sustainable	550 b	697 b	624 a	19.6 a	20.4 a	20.02 a	1.7 a	4.4 a	3.1 a
Convent.	570 b	557 b	564 a	20.9 a	20.6 a	20.80 a	1.8 a	0.5 a	1.2 a
Mean myc.	591 n.s.	608 n.s.		21.1 n.s.	20.4 n.s.		1.6 n.s.	2.8 n.s.	

[1]Mycorrhiza; [2]Without mycorrhiza; [3]Production system

The main purpose of agriculture in general is to achieve highest possible yields with less possible costs, in this way the final product costs less and the profits are higher (Abdul-Baki, 1998). Therefore endive yields per unit area are very important. In our research endive yields were tested through several factors. The results showed that production system and mycorrhiza and both their interaction had no significant influence on yields. Based on these evident we can conclude that available amounts of nutrients (applied by manure) which were differently applied in production systems (sustainable and conventional) and not used in organic (only plant mulch of hairy vetch and fodder pea was tilled in) had no effects on increased yields. Different pest treatment also had no effects on endive yields. Endomycorrhiza also had no effects on endive yields although the nutrition status was low (88 N kg/ha in sustainable system, and no manure used in organic system). Concerning other authors (Osvald et al., 2002) manure should be applied in larger doses (150 kg N/ha, 50 kg P_2O_5/ha, 250 kg K_2O/ha). In sustainable production basic soil ploughing and basic fertilization was not possible because of PE mulch laid down for preceding crops. Therefore less additional fertilizers were used. Fertilizer was used two times in sustainable production and four times in conventional production system, in the first month and half of vegetation. We could manure forwards but that would cause no effects on yields and would cause increase on nitrates in endive leaves (at the time the temperatures were lower and days shorter what causes nitrates accumulation). Similar nitrate accumulation in head chicory was found by Ćustić (1996). All three systems of production produced about 20 tons/ha although the possible yield could have been higher, up to 40 tons/ha, which had been achieved in endive production (Osvald et al. 2002). The reasons that yields were not at the maximum lye not in manure management, because in the organic system we used no manure, still the yields were the same as the yields in sustainable and conventional production, what once more approves the mentioned statement that endive is a very tolerant vegetable culture.

The only true reason for minor yields in our research should be explained through plant density (4 plants/m^2), which should be at least double (10-15 plants/m^2) according to research findings of Tesi (1990) and Osvald et al. (2002). Therefore, if got yield, that was amounting 20 t/ha, multiply with double number of plants, get of a final during 40 t/ha yield, which in own parts list also Tesi (1990) and Osvald et al. (2002).

First production year had consequences on shares of non-marketable production (Table 4). Organic production had 3%, respectively 2% more non-marketable endive mass from total production comparing to sustainable and conventional production. However these differences were not proved in the second research year. Reasons were climatic conditions which in the first year were favourable for disease development. Just before harvesting in organic production endive was attacked by *Botrytis cinerea* therefore a number of plants were damaged and not suitable for market sales. Inoculation with mycorrhiza and the interaction of production systems and mycorrhiza had no effects and shares of non-marketable yields. Significant differences in research of lettuce were also not proved (Ban et al., 2003). Therefore once more we proved that endive is a very tolerant vegetable culture with few requests in production.

CONCLUSIONS

Through several field researches it is determined that endive can be successfully grown in organic production system with total omission of chemical means (mineral manure and chemically produced pesticides). Such production achieves yields which are expected in sustainable and conventional production. Because of stated findings, endive is recommended for organic production. Inoculation of transplants with the fungus *Glomus mossae* had no effect on endive production in our research.

Endive production as a succeeding crop is possible without significant yield diminishment and has positive effects on using PE mulch from the preceding culture in sustainable and conventional production systems, while in organic production it uses the plant mulch ploughed in for succeeding crops.

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