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ALPHA AND BETA PLANT DIVERSITY IN MULTISPECIES AGROECOSYSTEMS OF CENTRAL GREECE

SUMMARY

Intercropping encourages biodiversity, by providing a habitat for a variety of plants, which benefit the population of insects and soil organisms that would not be present in a single-crop environment. The literature about this issue is scarce. Hence, the study of plant species density, alpha (species richness, Shannon, Simpson and Evenness index) and beta diversity (Jaccard similarity index) were held in the University of Thessaly facilities on May 2014, with the use of sample plot (50 x 50 cm). The experimental plots were constituted of the following types of intercropping: Pea-Oats (P-O), Pea-Barley (P-B), Winter Vetch-Oats (WV-O), Winter Vetch-Barley (WV-B), Grass Pea-Oats (GP-O) and Grass Pea-Barley (GP-B). A total number of eight species of herbaceous plants were recorded in all types of intercropping. The average density of herbaceous plants was found significantly higher in the Pea-Barley (21.80 ± 13.68, $p < 0.05$) than the Pea-Oats (10.00 ± 7.61, $p < 0.05$), Winter Vetch-Oats (10.60 ± 17.79, $p < 0.05$), Winter Vetch-Barley (6.80 ± 9.47, $p < 0.05$), Grass Pea-Oats (13.00 ± 12.20, $p < 0.05$) and Grass Pea-Barley (5.00 ± 5.91, $p < 0.05$). The Shannon diversity index was higher in the Pea-Barley (1.33) and lower in Winter Vetch-Oats (0.00), Winter Vetch-Barley (0.00) and Grass Pea-Barley (0.00) ($p < 0.05$). The results also showed that the type of intercropping Pea-Barley (1.00-0.85) favoured the evenness and similarity of plant species in relation to other types of intercropping ($p < 0.05$). Conclusively, intercropping systems clearly have the potential to increase the long-term sustainability of food production under low inputs. Specifically, the type of intercropping Pea-Barley favours alpha and beta plant diversity making this type of intercropping important, favouring parameters of biodiversity both in Greek and in the wider Mediterranean areas. We conclude, also, on the need to enhance agricultural research on these multispecies systems, combining both agronomic and ecological concepts and tools.

Keywords: sustainability, crops, biodiversity, Mediterranean.

INTRODUCTION

Intercropping systems consist of two or more crops growing together and coexisting for a time. This final criterion distinguishes intercropping from mixed

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mono-cropping and rotation cropping (Li et al., 2013; Brooker et al. 2015). Intercropping is common in countries with high amounts of subsistence agriculture and low amounts of agricultural mechanization. Intercropping is often undertaken by farmers practising low-input, low-yield farming on small parcels of land (Ngwira et al., 2012; Brooker et al. 2015).

Most studies on intercrops systems reporting legume-cereal intercropping, a productive and sustainable system, a resource facilitation which consist of growing, soil's fertility and yield. Latati et al. (2013) confirmed the advantage of intercropping legumes – cereals over sole cropping system, as sustainable agriculture.

The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture (Agegnehu et al. 2008). Reversely, Ofori et al. (1987) indicated that intercropping system causes a decrease of yield due to the problems of harmful grasses, pests and diseases, in addition to the difficulties of harvesting.

Intercropping can conserve soil water by providing shade, reducing wind speed and increasing infiltration with mulch layers and improved soil structure (Young 1997). Spatial arrangement of intercrops is an important management practice that can improve radiation interception through more complete ground cover (Heitholt et al., 2005).

Intercropping of compatible plants also encourages biodiversity, by providing a habitat for a variety of plants, insects and soil organisms that would not be present in a single-crop environment. This in turn can help limit outbreaks of crop pests by increasing predator biodiversity (Altieri and Nicholls 2004). Plants form the critical base of food chains in nearly all ecosystems. Through photosynthesis, plants harvest the energy of the sun, providing both food and habitat for other organisms. Therefore, the study of plant diversity constitutes the key of the ecological balance in the intercropping ecosystems.

The literature about the above issue is scarce. Few studies have examined the role of plant functional diversity and the concept of overyielding in food production systems. Hence, the aims of this study is the estimation of plant species density and alpha diversity (species richness, Shannon, Simpson and Evenness index) in the following types of intercropping: pea-oats (p-o), pea-barley (p-b), vetch-oats (v-o), vetch-barley (v-b), vetch-oats (v-o) and vetch-barley (v-b) providing environmental services that have impacts beyond the field scale, either spatially, e.g. services to the local or the global community, or temporally, e.g. modifications of the environment for future generations.

MATERIAL AND METHODS

A number of field experiments have been carried out in Thessaly plain (Experimental Farm of the University of Thessaly, Velestino, central Greece, 2014) with coordinates Lat: 390 23', Lon: 22° 45', and altitude 87.5 m (Fig.1). The soil at the site was a deep, moderately fertile, clay loamy soil that was classified as Calcixerollic Xerochrept (USDA, 1975).

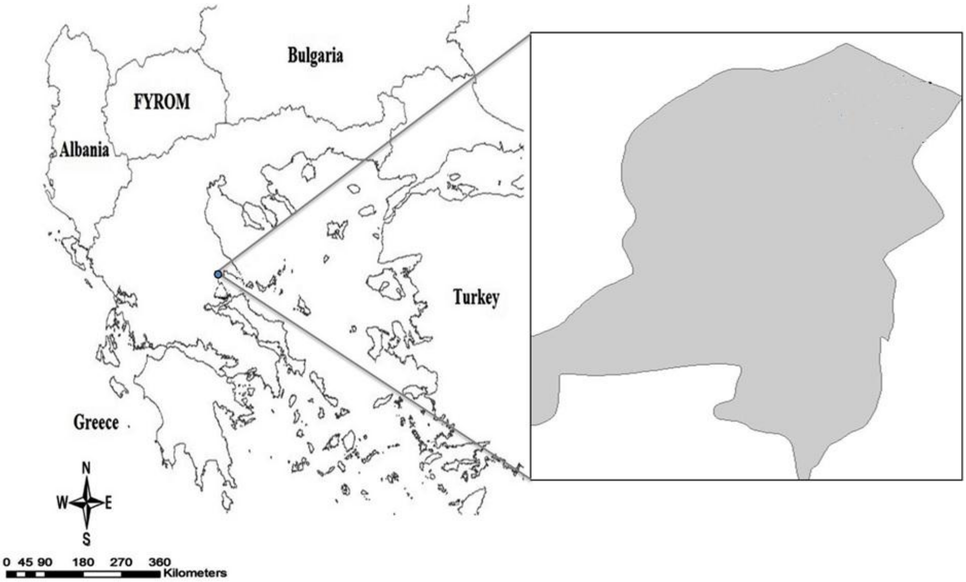

Figure 1. Study area

The study area is part of the *Quercion ilicis* and *Oleo-Ceratonion* subzones of the *Quercetalia ilicis* zone of the Mediterranean-type vegetation at altitudes up to 50 m a.s.l. (above sea level).

The climate in Greece is typical Mediterranean with cool humid winter and very dry and hot summer. Thessaly, the largest Greek lowland and the centre of the country's agricultural production, is characterized by a more continental climatic character with colder winters and hot summers.

Sampling

The sampling of herbaceous vegetation was carried out in May 2014 in randomly selected plots of 0.25 m^2, in order to estimate plant density and diversity (Cook and Stubbendieck 1986, Solomou and Sfougaris 2013) (Fig. 2).

Data were evaluated for normality and homogeneity with the Kolmogorov–Smirnov and Shapiro–Wilk tests. Data were transformed using log(x + 1) when necessary to meet normality assumptions. For the analysis of plant data, a general linear model (GLM, Type III Sum of Squares) (one-way ANOVA) was used. Tukey's HSD (honestly significantly difference) pairwise comparison tests were used with $p < 0.05$. Statistical analyses were performed using the software package IBM SPSS Statistics ver. 19.0 for Windows (SPSS Inc., IBM Company, Chicago, IL, USA 2010).

Several alpha-diversity indices such as species richness, Shannon–Wiener, Simpson and evenness were calculated using Species Diversity and Richness IV software (comparisons among the type of intercropping systems were made with the randomization test of Solow (1993), Seaby and Henderson 2006). For a detailed description of the mathematical background of the above indices, see

Seaby and Henderson (2006). A variety of methods for measuring beta diversity are available, among them similarity measures are the simplest and the most commonly used, being calculated from presence/absence data (Koleff et al. 2003). The similarity of plant communities among the types of intercropping systems was examined using the Jaccard index (Koleff et al. 2003) to express beta diversity, again using Species Diversity and Richness IV software (Seaby and Henderson 2006).

Figure 2. Sampling quadrate of 0.25 m^2 (0.5 m × 0.5 m)

RESULTS AND DISCUSSION

A total number of eight species of herbaceous plants were recorded in all types of intercropping in the study area [three (Pea-Oats), four (Pea-Barley), one (Winter Vetch-Oats), one (Winter Vetch-Barley), three (Grass Pea-Oats) and one (Grass Pea-Barley)] (Table 1). The highest mean density of herbaceous plants (21.80±13.68 individuals/m2, $p<0.05$) (Figure 3) were recorded in the Pea-Barley. Tengberg (Salas et al. 1997) indicates that diversity of agricultural systems, agricultural species and main species are three component of agrobiodiversity. Multiple cropping, especially intercropping, is one way to increase agroecosystems diversity (Marshall et al. 2003, Azizi et al. 2015).

Mohler, and Liebman (Mclaughlin and Minrau 1995) demonstrated that intercropping of barley and pea and barley monoculture were similar in plant species richness approximately. However, plant species richness in pea was the most (Mahn 1984, Mclaughlin and Minrau 1995, Azizi et al. 2015).

The type of intercropping pea-barley showed the highest similarity in plant species composition (table 1). Beta diversity is an important property of ecosystems because it provides information about the partitioning of habitats by species and constitutes an empirical and theoretical link between alpha (the local diversity of a community) and gama diversity (Cornell & Lawton, 1992; Medianero et al. 2010). It captures a fundamental aspect of the spatial pattern of diversity, and its study is fundamental to understanding the geographic patterns of species richness (Whittaker, 1972; Koleff, 2005; Medianero et al. 2010).

Table 1. Herbaceous plant species in the study area.

Species	Family	Type of intercropping					
		Pea-Oats	Pea-Barley	Winter Vetch-Oats	Winter Vetch-Barley	Grass Pea-Oats	Grass Pea-Barley
Anthemis arvensis	Asteraceae	+	+				
Chrysanthemum segetum	Asteraceae				+		
Sinapis arvensis	Brassicaceae	+					+
Sinapis alba	Brassicaceae					+	
Convolvulus arvensis	Convolvulaceae	+	+			+	
Papaver rhoeas	Papaveraceae		+				
Avena sterilis	Poaceae		+			+	
Hordeum murinum	Poaceae			+			

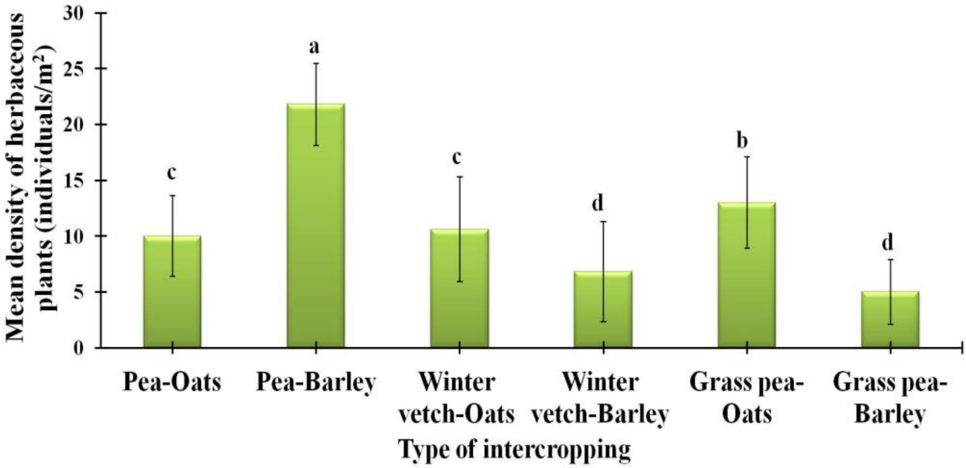

Figure 3. Mean density of herbaceous plants in all types of intercropping

Factors influencing species turnover among local fauna are usually a combination of environmental and geographical variables (i.e. Geographic distance) (Borcard et al. 1992), and determining their relative weighting is crucial for understanding the shaping of biogeographic patterns (Duivenvoorden et al. 2002, Medianero et al. 2010).

Table 2. Alpha and Beta plant diversity in all types of intercropping.

Index	Type of intercropping					
Alpha diversity	Pea-Oats	Pea-Barley	Winter Vetch-Oats	Winter Vetch-Barley	Grass Pea-Oats	Grass Pea-Barley
Species richness	3	4	1	1	3	1
Shannon	0.97	1.33	0	0	1.02	0
Simpson	2.42	3.74	1	1	2.64	1
Evenness	0.46	0.64	0	0	0.49	0
Beta diversity						
Jaccard	0.86	0.91	0	0	0.84	0

CONCLUSIONS

Intercropping systems clearly have the potential to increase the long-term sustainability of animal food production under low inputs. Specifically, the type of intercropping - nitrogen symbiosis fixation by legume was used as important resource for intercropping during growing cycle of cultivated plants – in Pea-Barley cultivation favours alpha and beta plant diversity making this type of intercropping important, favouring parameters of biodiversity both in Greek and in the wider Mediterranean areas.

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