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RESEARCH ARTICLE

Changes in plant species diversity as affected by shading conditions and continuous agricultural practices in kiwifruit orchards

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ABSTRACT

The environmental impact of commercial Mediterranean kiwifruit 'Hayward' orchards was assessed after ten years of continuous cultivation. Species diversity seems to be influenced both by the subcanopy photosynthetically active radiation (PAR) budget, and the usual agricultural practices in conventional orchards. The largest reduction of species diversity (~64%) was observed in kiwifruit orchards with pergola canopy structure followed by that in T-bar canopy structure (~34%) in comparison with new installed kiwifruit orchards. In excessive shading conditions and particularly in well irrigated kiwifruit orchards with the synergistic effect of the above variables, the highest reduction of plant species has occurred. The continuous herbicides application and the soil compaction are strongly correlated with the reduction of taxa, while the long-term agricultural practices, such as inorganic fertilizers and Cu-fungicides application, have a negative impact on plant species diversity in kiwifruit orchards.

Keywords: kiwifruit; orchards canopy; shading effect; edaphic properties; plant species diversity

INTRODUCTION

The agroecosystem is a dynamic system where plant species - soil/climate variables and agricultural practices interact. The heterogeneity of local environment and the capacity of the taxa to utilize the available resources, affect plant species diversity. Usually, the agri-environment schemes lead to a more efficient use of available growth resources (nutrient, water, light) with positive impacts in crop yields, often creating unfavorable conditions to native plants species. Moreover, stressful environmental variables such as long-term pesticide use, heavy metal contamination, soil compaction, severe changes of soil pH values etc., tend to influence plant species diversity in cultivated land (Fridley 2003).

The agricultural practices in intensive orchards can usually modify some agricultural climate/soil variables and plant species diversity (Palm et al., 2014). Kiwifruit has recently been one of the most dynamic cultivation in the Mediterranean basin contributing to the 25% of the world Kiwifruit production with 940 thousand metric tons. Italy and Greece represent the leading EU Kiwifruit producers, followed by France (FAOSTAT 2021). In particular, Greece contributes to the 28% of EU-28 Kiwifruit production. The commercial kiwifruit varieties came directly or indirectly from selected native species of *Actinidia chinensis* Lindl. where endemic plants "yang tao" climb on trees in China (Huang and Liu, 2014). Once domesticated, the new kiwifruit cultivars expanded rapidly, and are now planted in agricultural areas not previously existing.

Like endemic plants, domesticated vine (kiwifruit) tends to climb and for this reason, technical support structures are constructed, creating artificial kiwifruit canopies in cultivation period. Commercial kiwifruits are trained onto trellis systems, usually above either T-bar or pergola support structures shaping a stand monolayer. Kiwifruit orchards are usually covered with anti-hail nets consisting a practice broadly used in many countries like Greece. These

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layers form a complex canopy structure with probable environmental interactions between biotic and abiotic factors. Previous studies mention that forest canopies, diminish or promote the coexistence of some native plant species (Nadkarni et al., 2011). However, covering kiwifruit orchards with nets causes artificial shading conditions since photosynthetically active radiation (PAR) is cumulatively intercepted both by the anti-hail nets and the kiwifruit canopy, with a substantial impact on plant species diversity. After all, the light competition is one of the most important factors which limits the plant species growth under the canopy of tree cultivation (Souza et al., 2013).

A crucial point related with the kiwifruit cultivation is whether agricultural interventions can lead to disruption of plant species diversity in intensive conventional agricultural systems or not. Despite the fact that there are sufficient studies on the quality and productivity of kiwifruit and its relation with soil fertility and anti-hail nets (Basile et al., 2012), there is a lack of studies, about the impact of the kiwifruit orchards structure on plant species diversity, which should always be taken into consideration for a suitable and sustainable land management in agro-environment.

In this study, we evaluate the effect of kiwifruit cultivation (*Actinidia deliciosa* (A Chev) Liang et Ferguson cv Hayward) on the edaphic parameters and plant species diversity in orchards with different support structures under loamy soils. Specifically, the aim of the present study was: (a) to evaluate the effect of technical and continuous agricultural practices on physicochemical soil characteristics under different kiwifruit canopy stratification and (b) to reveal which environmental parameters are the most sensitive and reliable indicators interacting with plant species diversity, in order to preserve both the total ecosystem production and the biodiversity on agricultural land.

MATERIALS AND METHODS

Study area

The study was conducted in 18 kiwifruit orchards situated in Western Greece (38° 37'N, 21° 17'E), at an altitude ranging from 27 to 31 meters, where the Hayward variety occupies 80% of the total kiwifruit cultivations. In this area, the mean annual temperature is 17.5 °C and the mean annual rainfall ranges from 800 to 1000 mm having seasonal variation. Using anti-hail nets is a main practice in these orchards, due to extreme climate phenomena that take place in the area. The basic support structures in kiwifruit orchards studied are the typical T-bar or pergola, which are designed to support the weight of about 40 tons/ha kiwifruits during full production periods.

Experimental set up

The study was carried out in two consecutive years 2019-2020, in conventional young (1-2 years old) and old (≥8- 10 years old) kiwifruit orchards with different kiwifruit canopy stratification types: (a) Young orchards without kiwifruit canopy or nets, (b) Old orchards with T-Bar canopy structure plus nets and (c) Old orchards with pergola canopy structure plus nets. In each one of the above a-b-c treatments 6 replications took place occupying an area of 1 ha. These eighteen orchards are in Agrinio valley, having approximately loamy soil.

Light interception by nets, expressed as percentage of incident photosynthetic active radiation (PAR), was calculated at midday by taking 10 readings of PAR in rapid succession above and 10 below the nets (Kosma et al., 2013) using a 60-cm Sunfleck Ceptometer (Decagon Devices, Pullman, WA, USA). In the same way, light intensity was calculated (cumulative light interception by nets + canopy structure) below the two different types of old kiwifruit orchards in terms of canopy stratification. All measurements took place between row of kiwifruit orchards during the cultivation period (April-October). In each treatment the mean light intensity was calculated between row of kiwifruit orchards. Agricultural practices and soil-climatic conditions are shown in Table 1.

Soil and plant species sampling

Soil sampling took place in two successive years (2019-2020) during the winter. A total number of 18 soil samples (six from each treatment, labeled through a GPS device) were collected. Each one of the samples consisting of 10 cores, were received between row, in depth of 0-30cm. Additionally, the soil bulk density (BD) was determined in undisturbed soil core (0-30cm).

Native plant species were collected from each one of the eighteen kiwifruit orchards from April to October (2019-2020). In particular, an area of one ha in each sampling field was used and data concerning the taxa presence/absence were recorded. Also, in order to "benchmark" plant species diversity, 27 reference fields were used from abandoned land in Agrinio valley which were mainly unaffected soils or at least minimally affected by anthropogenic activities as already reported in previous study by Triantafyllidis et al. (2020).

Data analysis

Soil samples were air dried, crushed and sieved through a 2-mm sieve. Particle size distribution was carried out using Bouyoucos's method. The soil texture of samples was defined according to USDA (Ditzler et al. 2017). In saturated paste electrical conductivity (EC) and pH were measured. $CaCO_3$ equivalent was determined by

Table 1: Typical agricultural management practices in kiwifruit orchards in the study area

	Actinidia deliciosa cv. 'Hayward'		
	Young orchards without canopy or nets	**Old orchards with T-Bar canopy structure plus nets**	**Old orchards with pergola canopy structure plus nets**
Planting density	Approximately up to 740 plants/ha (3-4m x 4.5-5m).	Approximately 400-500 plants/ha (4.5-5m x 4.5-5m).	Approximately up to 740 plants/ha (3-4m x 4.5-5m).
Anti-hail nets	Without nets yet	Nets with shading level about 25%	
Pruning strategies	In the second year shape pruning starting	They are often designed to provide optimum bud loads (18-28 canes/tree)	
Flowering	50% flowers open occurred early May (2018 & 2019 year)		
Fertilization	In the young plants growers used N-P-K fertilizers. Usually, phosphorus used in larger doses in young plants in order to get vigurus plants and to establish a good root system. Potassium used in smaller doses in young plants compared to older ones. Foliar sprays used for microelements deficits, according to the soil analysis and the problems which need to manage. Also, sheep manure was added by some growers.	Most of kiwifruit growers annually follow a fertilization program with NPK-mineral fertilizers (12:12:17 or 13:10:20 or 11:15:15): March: 400 Kg/ha; April: 400 Kg/ha; November (post-harvest fertilization): 100-200 Kg/ha. Moreover, liquid fertilizers by Foliar sprays or fertigation were applied: complete liquid fertilizer, soil activator; 12-0-0+8 Zn; 10-0-0, 50% aminoacids with growth substances; Calcium chelated with aminoacids, organic potash 30%. Plant biostimulants and plant growth regulators were applied: Erger; BENEFIT® PZ; MC-CREAM; Sitofex. Soil enrichment with rhizosphere bacteria, fungi spores and plant symbiotic endomycorrhizal fungi. Also, sheep manure was added by some growers.	
Plant protection	No herbicides are used on young plants. The same approved fungicides and insecticides are used in smaller doses compared to older plants, depending on the pest and diseaces problemes they need to manage. Ussualy, smaller problemes observed in younger orchards.	Herb: Rodeo Plus (a.i.: Glyphosate 36%, approx. annual dose 2000 gr a.i./ha, one spray/year until March). Fungi: Cu-fungicides from January to mid-February, approximately annual dose 2500-3000gr Cu/ha. Cu-fungicides widely used such as Nordox (a.i. Copper oxide, 2 sprays/year December and after winder pruning). At the stage of flowering, a preventive application is made to treat Botrytis cinerea, with: Serenade Max WP (a.i. Bacillus subtilis QST 713); Mevalone CS (a.i. Eugenol-Geraniol-Thymol); Geoxe 50 WG (a.i. Fludioxonil).	
Grass shredder	Grass shredder was used, the grass biomass is left in place to decompose		
Irrigation	Sprinkler irrigation from early-June until late-September, irrigated day per day. Irrigation dose: 450 to 600 m^3/ha/year.	Sprinkler irrigation from early-June until early September, irrigated day per day. Irrigation dose: 900 to 1200 m^3/ha/year.	
Harvest yield	Not yet	Mean yield: 40.000 Kg per ha.	
Soil	Parent material: Holocene alluvium, Quaternary terraces; Dominannt STU (Soil Unit Type): Calcaric Fluvisol (FLca); Associated STU: Calcaric Cambisol, Haplic Calcisol, Rhodic Luvisol; Slope gradient: 0%.		
Climate	Mediterranean, characterized by hot dry summers and cold humid winters. Mean annual precipitation: 890mm, with 70% falling over the period November to March, and mean annual temperature: 17.5°C.		

using Bernard-calcimeter. Soil organic matter (SOM) was determined by the method Walkley-Black, while SOM concentrations were converted to SOC (Soil Organic Carbon, g/Kg) as follows: SOC = SOM×0.58. Available-P (P_{Olsen}) was measured according to Olsen method. Exchangeable Ca-Mg-K and Na were extracted with 1N (NH4OAc at pH7.0) ammonium acetate (Thomas 1982). The extracted solutions of potassium and sodium were analyzed by flame photometer (Jenway-PFP7), while those of Ca and Mg by flame AAS (Analyst-700 by Perkin Elmer). Also, DTPA-extractable (Lindsay and Norvell 1978) Cu-Fe-Mn, and Zn were analyzed using AAS-analyzer. The Total-N was estimated using the Kjeldahl method (model UKD-130 by Velp). The determination of NO^-_3 was performed in 1:10 water-extracts. The extracted solutions of NO^-_3 were analyzed by Dionex-1500-Ionic.

Plant specimens were identified to species level mainly according to Tutin et al. (1968–80, 1993). Plant nomenclature follows Dimopoulos et al. (2013; 2016).

Statistical analysis

Nineteen soil physicochemical properties (Table 2) were used in order to estimate the effect of continuous cultivation practices on edaphic properties and plant species richness in kiwifruit orchards. Descriptive statistics was used to quantify soil properties. Statistical analysis was carried out using SPSS version-20. Principal component analysis (PCA) was used to assess how many and which of the above (19) mentioned parameters can be considered as representative edaphic indicators correlated both to native plant species presence/absence in kiwifruit orchards and the environmental changes

Table 2: Soil fertility status of kiwifruit orchards, comparison of the mean ± standard deviation values of the examined edaphic properties after long term cultivation in Western Greece

Edaphic properties	Young orchards without canopy or nets (*yw*) (n=6)	Old orchards with T-Bar canopy structure plus nets (*olt*) (n=6)	Old orchards with pergola canopy structure plus nets (*olp*) (n=6)	All kiwifruit orchards (n=18)		*EF* or *DF*[a]	*EF or DF*[b]
	mean ± S.D.	mean ± S.D.	mean ± S.D.	mean.	S.D.	*olt/yw*	*olp/yw*
pH	7.77 ± 0.35*	8.17 ± 0.30*	8.15 ± 0.20*	8.03	0.33	1.05	1.05
BD	1.39 ± 0.02*	1.46 ± 0.04*	1.43 ± 0.02*	1.42	0.04	1.05	1.03
EC dS m^{-1}	0.47 ± 0.11	0.63 ± 0.30	0.51 ± 0.17	0.54	0.21	1.34	1.09
Clay (%)	20.9 ± 3.80	22.1 ± 3.07	23.1 ± 2.17	22.0	3.04	1.06	1.11
Silt (%)	44,3 ± 7.70	40.4 ± 6.42	38.7 ± 4.99	41.2	6.54	0.91	0.87
Sand (%)	34.8 ± 5.63	37.5 ± 5.39	38.2 ± 6.83	36.8	5.82	1.08	1.10
total $CaCO_{–3}$ (%)	3.75 ± 2.77	4.15 ± 2.70	3.92 ± 2.70	3.94	2.70	1.11	1.05
SOC (g Kg^-¹)	6.93 ± 1.39	9.95 ± 5.12	8.59 ± 1.72	8.49	3.28	1.44	1.24
Total N (g Kg^{-1})	0.89 ± 0.24	0.87 ± 0.24	0.81 ± 0.21	0.85	0.22	0.98	0.91
Exch.Ca (meq/100gr)	17.6 ± 5.34	21.3 ± 4.43	18.7 ± 4.60	19.2	4.79	1.21	1.06
Exch.Mg(meq/100gr)	2.80 ± 1.49	2.53 ± 1.84	2.64 ± 1.41	2.66	1.50	0.91	0.95
Exch.K (meq/100gr)	0.55 ± 0.22	0.70 ± 0.35	0.54 ± 0.17	0.59	0.26	1.27	0.98
Exch.Na (meq/100gr)	0.26 ± 0.09	0.33 ± 0.08	0.33 ± 0.07	0.31	0.08	1.25	1.25
NO_3-N (mg Kg^{-1})	6.67 ± 3.83	10.1 ± 7.11	8.40 ± 4.50	8.39	5.22	1.52	1.26
P_{Olsen} (mg Kg^{-1})	18.7 ± 9.34	16.0 ± 12.6	15.7 ± 12.0	16.8	10.8	0.85	0.84
Zn_{DTPA} (mg Kg^{-1})	0.97 ± 0.69	1.10 ± 0.82	1.33 ± 0.60	1.13	0.68	1.13	1.37
Mn_{DTPA} (mg Kg^{-1})	13.6 ± 4.64	9.95 ± 5.12	12.0 ± 5.89	11.8	5.16	0.73	0.88
Fe_{DTPA} (mg Kg^{-1})	17.9 ± 11.2	15.2 ± 6.20	12.3 ± 4.24	15.1	7.70	0.85	0.69
Cu_{DTPA} (mg Kg^{-1})	1.97 ± 0.47*	3.19 ± 1.40*	3.41 ± 0.89*	2.86	1.14	1.62	1.73

*Indicates significant differences at significance level *P*<0.05 based on one-way anova test results among three different treatments in kiwifruit orchards

arising from the agricultural practices (Triantafyllidis et al., 2020).

CANOCO software version-4.5 (Ter Braak and Šmilauer, 1998) and in particular Canonical Correspondence Analysis (CCA) was used in order to assess the effect of multivariable environmental factors on plant species distribution pattern. The statistical significance of the relation between the plant species and the environmental variables was assessed using Monte Carlo significance test (499 random permutations). Step-wise analysis through forward selection was used to test the significance and strength of the explanatory variables of each variable group, holding each time one of them constant as covariates. In addition, the ordination of the sampling fields as a result of their interaction with the environmental variables was recorded.

RESULTS AND DISCUSSION

Soil fertility status in kiwifruit orchards

Descriptive statistics on some topsoil properties resulting from the laboratory analysis are shown in Table 2. Loamy soil was observed in all kiwifruit orchards, while soil samples were classified in three textural classes: L (66.7%), SiL and CL with the same percentage (16.7% of total samples). Soil pH reaction of samples was slightly and moderately alkaline in 5.6 and 94.4% respectively. The EC values (ds/m) ranged from 0.26 to 1.19. BD values (g/cm^3) ranged from 1.37 to 1.51. In Calcaric Fluvisols of the study area (Yassoglou et al., 2017), the content of total-$CaCO_3$ was rich (55.6% of total samples). The SOC ranged from 4.7 to 19.3 g/Kg, while in 66.7% of kiwifruit orchards the content of SOM was low (<1.5%). Additionally, the concentration of Total-N shows a similar trend, since in the 100% of the collected soil samples ranged at low levels (<1.5 g/Kg). Also, the macro-micronutrients soil fertility status of kiwifruit orchards is showed in Table 2. It was remarkable that 100% of the soils were excessive inCu_{DTPA} concentrations (opt. 0.5-1.0 mg/Kg). Additionally, no statistically significant differences from physicochemical soil properties were observed among treatments, except for BD, soil pH values and Cu_{DTPA} concentrations. All these three agricultural soil variables were significantly increased with cultivated practices, as the kiwifruit orchards grew older (Table 2).

After, long-term kiwifruit cultivation, only 16% of soil physicochemical properties (pH, BD and Cu_{DTPA}) presented significant differences (Table 2). The highest BD values were observed in soil samples which were taken between row, in old kiwifruit orchards due to the extensive use of vehicle traffic to perform agricultural practices. Similar results were observed in other kiwifruit (Carey et al., 2009) and almond orchards (Becerra et al., 2010). Soil pH was increased due to the high content of $CaCO_3$ and the frequently followed agricultural practices. Moreover, higher Cu_{DTPA} was observed in old kiwifruit orchards. These significant higher Cu_{DTPA} concentrations, between young and old orchards, are attributed to the successive inputs of Cu, amounting to 3,000 gr/ha each year (Table 1). The "hidden" Cu-impurities of inorganic fertilizers and mainly the broad use of Cu-fungicides are responsible for the excessive Cu_{DTPA} concentration of Cu_{DTPA} in orchard cultivations (Ballabio et al., 2018). These excessive Cu_{DTPA} concentrations have a negative impact both in kiwifruit production (Wang et al., 2019) and plant species diversity in cultivated land (Poschenrieder et al., 2001). The results suggest that commercial kiwifruit orchards respond to edaphic properties, but they also affect them, influencing both soil quality and fertility.

Edaphic indicators assessment in the selected kiwifruit orchards

In PCA, after applying varimax rotation factor analysis four principal components were revealed (PC1-PC2-PC3-PC4, Eigenvalue >1). Those components represent 79.25% of cumulative variance (Table 3). PC1 is defined by soil reaction and its effect on the availability of macro and micro elements, PC2 is defined by soil fertility and how it is affected by the agrochemicals use and the following agriculture practices, PC3 is defined by soil physical conditions such as soil texture indicators sand/silt/clay, while PC4 is attributed to alkaline earth metals attached to organic constituents of soils which can be exchanged with each other and with other positively charged ions in soil solution. The PCA matrix showed that P_{Olsen}, NO^-_3, Silt, K_{exch} were the edaphic indicators with the highest factors loading in each PC of all the other edaphic variables. However, it is often difficult to define which soil factor affects directly the availability of a certain nutrient and which factor is only in "pseudocorrelation" with the nutrient. Sillanpää (1982) reported that in practical nutrient studies a "pseudocorrelating" soil factor might often be as informative as a factor of direct effect. Considering the above-mentioned and after the interpretation of PCA, the results showed that: in calcaric soils the higher pH values have strong negative correlation with P_{Olsen}, Mn_{DTPA}, Fe_{DTPA} available concentrations, which is in accordance with Moore et al. (2014). Therefore, in PC1 the edaphic indicator P_{Olsen} represents these interactions in soil of kiwifruit orchards. In PC2, EC values and NO^-_3 concentrations were strongly correlated, probably due to fertilizers application rate, which is in accordance with previous studies (Patriquin et al., 1993; Triantafyllidis et al., 2018). Also, NO^-_3 concentrations were correlated with SOC, Total-N, Zn_{DTPA} concentrations and soil texture, which is in accordance with previous studies (Carey et al., 2009). As shown, this PC2 was affected mainly by the application of inorganic and less by organic fertilizers in conventional kiwifruit orchards. This interaction is better represented by the soil indicator . PC3 clarifies the important role of soil particle size by describing some of the physical soil conditions. This edaphic indicator (silt) was representative of loamy soils in the study area. PC4 describes the soil behavior of alkaline earth metals and their "pseudocorrelation" with other nutrients. In calcaric soils of the study area, despite the use of fertilizers, 55.6% of soils were deficient in potassium (K_{exch} opt. conc. 0.6-0.8 meq/100gr). In contrast, 61.1% of soils showed an excessive concentration of Ca_{exch} (opt. conc. 6.0-18 meq/100gr). Previous studies showed that the nutrient status prevailing in cultivated land is a result of the cationic antagonism that occurs among , Ca_{exch}, Mg_{exch} and K_{exch} concentrations in soil (Rhodes et al., 2018). As a result, the most sensitive and reliable agricultural soil variables (P_{Olsen}, NO^-_3, Silt, K_{exch} and BD and Cu_{DTPA}) were used to estimate the effect of kiwifruit orchards on edaphic properties and plant species diversity in cultivated land (Tables 2&3).

Shading conditions in different kiwifruit canopy formations

Between row of kiwifruit orchards, significant differences of light intensity (cumulative light interception by nets + kiwifruit canopy) were calculated below each of the three canopy stratification types: (1) 100% of Full Ambient Light (FAL) in control treatments (Young orchards without

Table 3: Matrix of principal component analysis of normalized physicochemical properties and elemental concentrations of the selected kiwifruit orchard soils in study area (significant loading factors are marked in bold)

Soil properties	Rotated component matrix			
	PC1	PC2	PC3	PC4
P_{Olsen}	-,920	-,154	-,200	
Ca_{exch}	,920	,125		-,134
Total $CaCO_3$	,918			
Mn_{DTPA}	-,898	-,103		
pH	,892	,229	-,154	,127
Fe_{DTPA}	-,808	-,180	,299	-,151
Na_{exch}	,743	,295	-,139	-,246
$N0_3$-N	,213	,927		-,135
EC	,183	,854		-,288
Zn_{DTPA}	,303	,760	,152	-,214
SOC	,292	,754	,407	,263
Total N	-,275	,624	,610	
Clay		,622	-,404	
BD		,537	-,392	,401
Cu_{DTPA}	,383	,498	,258	,184
Silt		-,145	,960	
Sand		-,162	-,867	
K_{exch}	,312			,857
Mg_{exch}	-,267	-,280	,105	,749
Eigenvalue	5,995	4,401	2,819	1,841
% of Variance explained	31,554	23,161	14,839	9,692
Cumulative % variance	31,554	54,716	69,555	79,246

canopy or nets); (2) 73% of FAL (Old orchards with T-Bar canopy structure plus nets); (3) 24% of FAL (Old orchards with pergola canopy structure plus nets). The maximum daily PAR values measured in a sunny day in control treatments ranged from 970 to 1243 μmol m^{-2} s^{-1} in autumn and spring, respectively.

The different artificial canopy stratification in commercial deciduous kiwifruit orchards, caused a light deficiency (cumulative light interception by anti-hail nets + canopy structure) in plants under the canopy, from April to October. In long-term kiwifruit orchards this specific agricultural climatic variable (FAL), expressed as a percentage of incident light intensity, is a crucial environmental variable for plant species diversity. Souza et al. (2013) reported that light competition is the main factor that limits plant growth under the canopy of tree cultivation. In long-term "permanent" artificial stratification of kiwifruit canopy structures, the different levels of PAR intensities may have affected differently the number of taxa which were observed in the three different types of canopy structures (Table 4). A higher reduction of taxa with a simultaneous reduction of families was observed in orchards under pergola than in T-bar canopy structure. However, in plants under the canopy of other plants occurred positive and negative interactions simultaneously. Holmgren et al. (1997) reported that in deep shade and in humid environments, plant growth was limited, due to physiological trade-offs. As a result, taxa were less tolerant under kiwifruit orchards which formatted deep shade and humid environments. This synergistic action of different shading conditions and sufficient ambient humidity at irrigated orchards "day by day" can explain this higher reduction of taxa in pergola compared to T-bar canopy (Table 4).

Overall, the largest number of taxa was recorded in young kiwifruit orchards (59 taxa) consisting the richest type,

Table 4: Taxa collected in different kiwifruit orchard [Old orchards with T-Bar canopy structure plus nets (*olt*); Old orchards with pergola canopy structure plus nets (*olp*) and Young orchards without canopy or nets (*yw*), during April to October 2019 and 2020, Western Greece. The color of the boxes defines presence (grey) or absence (white)

Species	***yw***	***olt***	***olp***	**Species (continued)**	***yw***	***olt***	***olp***
Amaranthus retroflexus L.	grey	grey	grey	*Hypericum perforatum* L.	grey	grey	
Daucus carota L.	grey	grey		*Oxalis pes-caprae* L.	grey		
Sonchus asper (L.) Hill	grey	grey	grey	*Plantago major* L.	grey	grey	
Sonchus oleraceus L.	grey	grey	grey	*Plantago lanceolata* L.	grey	grey	grey
Cichorium intybus L.	grey			*Agrostis stolonifera* L.	grey	grey	
Cirsium arvense (L.) Scop.	grey	grey		*Digitaria sanguinalis* (L.) Scop.	grey	grey	grey
Crepis sancta (L.) Bornm.	grey			*Poa trivialis* L.	grey	grey	grey
Senecio vulgaris L.	grey			*Sorghum halepense* (L.) Pers.	grey		
Erigeron bonariensis L.	grey			*Polypogon monspeliensis* (L.) Desf.	grey	grey	grey
Xanthium strumarium L.	grey			*Echinochloa crus-galli* (L.) P. Beauv.	grey	grey	grey
Dittrichia graveolens (L.) Greuter	grey			*Cynosurus echinatus* L.	grey		
Crepis foetida L.	grey	grey	grey	*Cynodon dactylon* (L.) Pers.	grey	grey	
Myosotis arvensis (L.) Hill	grey	grey		*Lolium rigidum* Gaudin	grey		
Echium plantagineum L.	grey			*Setaria pumila* (Poir.) Roem. & Schult.	grey	grey	grey
Capsella bursa-pastoris (L.) Medik	grey	grey	grey	*Paspalum distichum* L.	grey	grey	
Cerastium glomeratum Thuill.	grey			*Alopecurus rendlei* Eig	grey	grey	
Stellaria media (L.) Vill.	grey	grey		*Setaria verticillata* (L.) P. Beauv.	grey	grey	
Atriplex prostrata DC.	grey	grey		*Hordeum murinum* L.	grey	grey	grey
Chenopodium album L.	grey	grey		*Polygonum lapathifolium* L.	grey		
Convolvulus arvensis L.	grey	grey	grey	*Rumex crispus* L.	grey	grey	
Cyperus rotundus L.	grey	grey	grey	*Polygonum aviculare* L.	grey	grey	
Knautia integrifolia (L.) Bertol.	grey	grey		*Portulaca oleracea* L. s. str	grey	grey	grey
Equisetum arvense L.	grey			*Anagallis arvensis* L.	grey		
Euphorbia helioscopia L.	grey	grey	grey	*Potentilla reptans* L.	grey	grey	grey
Melilotus indicus (L.) All.	grey			*Rubus sanctus* Schreb.	grey	grey	grey
Medicago orbicularis (L.) Bartal.	grey	grey	grey	*Galium aparine* L.	grey		
Medicago polymorpha L.	grey	grey		*Solanum nigrum* L.	grey	grey	grey
Vicia sativa L.	grey			*Urtica dioica* L.	grey		
Trifolium repens L.	grey	grey	grey	*Veronica persica* Poir.	grey		
Geranium dissectum L.	grey	grey		**Total number of species**	yw	olt	olp
					59	39	21

followed by the orchards under T-bar and pergola canopy structures with 39 and 21 taxa, respectively (Table 4). The families with the greater number of taxa were Poaceae, Fabaceae and Asteraceae in all different types of kiwifruit orchards (Table 5), while in those with pergola canopy structure only 12 of the total 26 families were observed. However, from a floristic point of view, the abandoned land includes 29 families and 94 taxa (data non shown), as has already been described in a previous study (Triantafyllidis et al., 2020). In this abandoned land no differences, in terms of species diversity, were observed 1-2 years later, revealing a stability of plant species diversity.

Ordination

The ordination of the sampling kiwifruit orchards, as a result of the interrelation between species composition and environmental variables, was also studied. The results are shown in CCA biplots (Figs. 1 and 2). According to Table 6, axes 1 and 2 represent the greatest amount of explanatory values (26% and 12% respectively). The CCA analysis of the sampling kiwifruit orchards, species and environmental variables based on the first two axes, explains the 49.1% of the variance (inertia) of data regarding species and the 67.4% of the variance in the weighted averages of the species with respect to the environmental variables (Table 6).

The examined environmental variables are represented in biplot graphs by arrows, whose length is proportional to the rate of change, in the direction of its maximum change along the diagram (Ter Braak, 1987). Among these environmental variables, the longest arrows are represented in axis by FAL, herbicides, Cu_{DTPA}, pH, BD and in axis 2 by K. These environmental variables which are more strongly correlated with the two main ordination axes and the variation patterns of species and sampling kiwifruit orchards are shown in the ordination diagrams (Figs. 1 and 2).

Along axis 1, mainly FAL, herbicides and secondarily Cu_{DTPA}, BD and pH explain the 97%, 88%, 54%, 52% and 45% of the species composition respectively, while along axis 2 the 31% of the species composition is explained by the K (Table 6). According to the CCA biplots ordination diagram a clearly distribution among the different kiwifruit orchards is observed (Fig. 1). Sampling plots which took

Table 5: Summary table of families and number of species per family among different kiwifruit orchards in terms of age and canopy structure. April to October 2019 and 2020, Western Greece

Families	Young orchards without kiwifruit canopy or nets		Old orchards with T-Bar kiwifruit canopy structure plus nets		Old orchards with pergola kiwifruit canopy structure plus nets	
	No of species	% presence of species	No of species	% presence of species	No of species	% presence of species
Amaranthaceae	1	1,69	1	2,56	1	4,76
Apiaceae	1	1,69	1	2,56	0	0,00
Asteraceae	10	16,95	4	10,26	3	14,29
Boraginaceae	2	3,39	1	2,56	0	0,00
Brassicaceae	1	1,69	1	2,56	1	4,76
Caryophyllaceae	2	3,39	1	2,56	0	0,00
Chenopodiaceae	2	3,39	2	5,13	0	0,00
Convolvulaceae	1	1,69	1	2,56	1	4,76
Cyperaceae	1	1,69	1	2,56	1	4,76
Dipsacaceae	1	1,69	1	2,56	0	0,00
Equisetaceae	1	1,69	0	0,00	0	0,00
Euphorbiaceae	1	1,69	1	2,56	1	4,76
Fabaceae	5	8,47	3	7,69	2	9,52
Geraniaceae	1	1,69	1	2,56	0	0,00
Hypericaceae	1	1,69	1	2,56	0	0,00
Oxalidaceae	1	1,69	0	0,00	0	0,00
Plantaginaceae	2	3,39	2	5,13	1	4,76
Poaceae	14	23,73	11	28,21	6	28,57
Polygonaceae	3	5,08	2	5,13	0	0,00
Portulacaceae	1	1,69	1	2,56	1	4,76
Primulaceae	1	1,69	0	0,00	0	0,00
Rosaceae	2	3,39	2	5,13	2	9,52
Rubiaceae	1	1,69	0	0,00	0	0,00
Solanaceae	1	1,69	1	2,56	1	4,76
Urticaceae	1	1,69	0	0,00	0	0,00
Veronicaceae	1	1,69	0	0,00	0	0,00

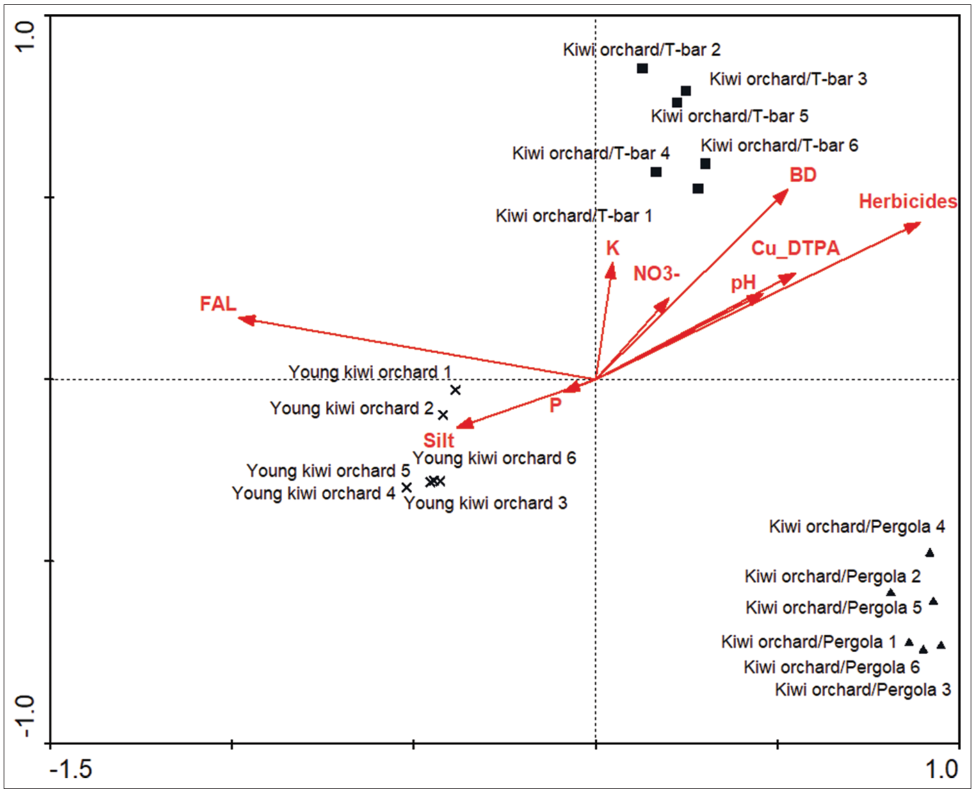

Fig 1. CCA biplot ordination diagram of the first two canonical axes 1,2 with sampling fields (x) in young orchards without kiwifruit canopy or nets, (■) in old kiwi orchards with T-Bar canopy structure plus nets, and (▲) in old orchards with pergola canopy structure plus nets and environmental variables (arrows).

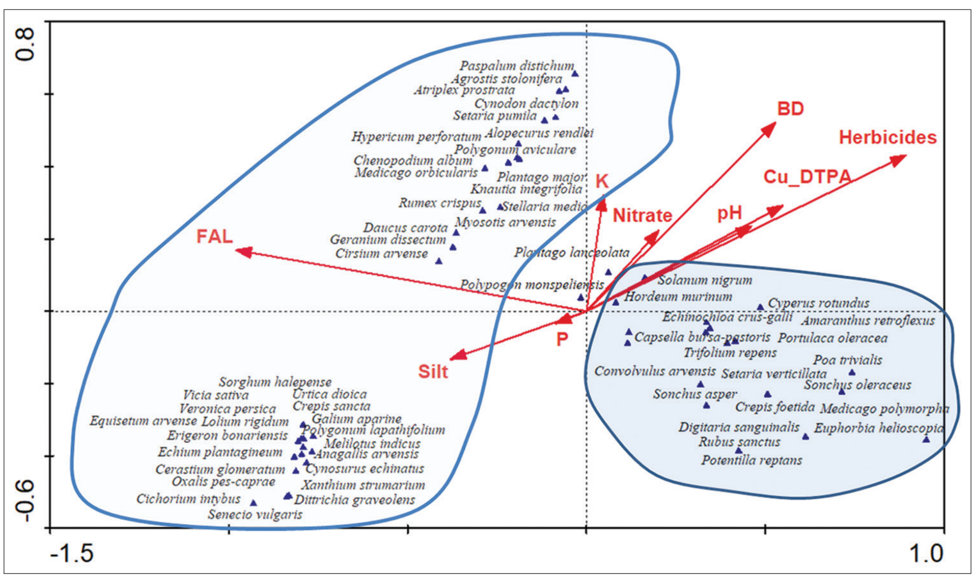

Fig 2. CCA biplot ordination diagram of the first two canonical axes 1, 2 with plant species and environmental variables (arrows) in sampling orchards of three different kiwifruit canopy stratification types.

place in old orchards with T-Bar canopy structure plus nets are grouped in the upper right part of the ordination diagram and are strongly correlated with Cu_{DTPA} , BD, pH and K. The young orchards without canopy or nets show medium to high positive score to axis 1, having a strong correlation with the FAL. From the left to the right side of the ordination diagram a gradient from more to less FAL condition can be distinguish. As a result, the kiwifruit orchards which are grouped in the lower part of the diagram are those of old orchards with pergola canopy structure plus nets, representing mainly negative correlation with the FAL.

Table 6: Correlations of environmental factors (BD, silt, pH, K, P, Nitrate, Cu_{DTPA} , FAL, herbicides) with the first two CCA axes, Eigenvalues of the ordination axes and sum of all unconstrained Eigenvalues (total inertia) for CCA analysis. April to October 2019 and 2020, Western Greece.

Environmental variables		Axis 1	Axis 2
BD		0.52	0.51
Silt		-0.37	-0.13
pH		0.45	0.23
K		0.04	0.31
P		-0.08	-0.03
Nitrate		0.20	0.22
Cu_{DTPA}		0.54	0.28
FAL		-0.97	0.16
Herbicides		0.88	0.42
Eigenvalues		0.26	0.12
Species-environment correlation		0.93	0.90
Cumulative percentage variance:			
(i) of species data		33.5	49.1
(ii) of species-environment relation		46.0	67.4
Total inertia:	0.78		
Sum of all eigenvalues:	0.78		
Sum of all canonical eigenvalues:	0.57		

According to the second CCA biplot ordination diagram a clear distribution between species was observed. In particular, two main groups were formed (Fig. 2). The first one is located in the left part of the diagram consisting of taxa which present positive correlation with the FAL and they are developed in places where the use of herbicides and the changes of pH and Cu_{DTPA} are limited or absent. In this group, a subgroup in the bottom left side of the diagram was observed, presenting positive correlation with the silt. The second group on the bottom right part of the diagram consists of taxa which have higher adaptability in pH, Cu_{DTPA} and BD changes, having also greater durability in herbicides use.

Intensification of kiwifruit cultivation and changes in plant species diversity

Higher reduction in the number of taxa was observed in kiwifruit orchards in comparison to the abandoned land. In particular, a reduction of 37%, 58 % and 78% of taxa was observed in young, old with T-Bar and old with pergola structure kiwifruit orchards, respectively. These differences are probably ought to the intensive agriculture and the wide use of agrochemicals which in turn cause changes in the quality of soils (Todd et al., 2011). This is in accordance with previous studies which report that about 40% of the taxa have been lost from the intensive agroecosystems mainly due to the monocultures and their needs of high levels of chemical inputs (Newbold et al., 2015). In addition, Egan and Mortensen (2012) observed that small areas of non-crop habitat, support a higher plant species diversity compared to the large areas with intensive cultivated fields. The extensive use of herbicides decreases the number of sensitive taxa, increasing at the same time taxa, which are resistant to them. After having applied active ingredients (a.i.) in crop fields, different transformation processes (biotic and abiotic) influenced a part of the herbicidal activity and their environmental fate. In previous years, herbicides with different active ingredients (triclopyr, aminopyralid, glufosinate-ammonium, glufosate) were applied only in kiwifruit orchards which were more than three years old (one spray per year). While, the last two years only the systemic herbicide with a.i. glyphosate was applied in old kiwifruit orchards. As shown in Fig 2, the impact of herbicides application was negative in plant species diversity. Probably, the synergistic action of herbicides use and the shading conditions which promote the herbicidal activity such as in the case of glyphosate (Getenga and Kengara, 2004; Heap and Duke, 2018; Gaba et al., 2017; PPDB 2021) reduced the number of taxa from 59 to 39 under old orchards with T-Bar canopy structure plus nets (Table 4).

On the other hand, continuous kiwifruit cultivation, improves some soil properties such as some nutrient concentrations (NO^{-}_{3}, Zn_{DTPA}), SOC content (*EF*: 1.44 and 1.24 in *olt* and *olp,* respectively) and it may deteriorate others as well, such as EC and pH values, N_{aexch}, P_{Olsen} and Total-N concentrations (Table 2). However, in conventional irrigated kiwifruit orchards, the shading conditions, the successive herbicides application and the broad use of Cu-fungicides, which cause high Cu_{DTPA} soil concentrations, have a negative impact on plant species diversity, under given soil (loamy soils) and microclimate (high humidity + shading effects) conditions.

CONCLUSION

The commercial 'Hayward' kiwifruit orchards create an unfavorable agricultural environment for some plant species which grow under canopy stratification. In excessive shading conditions and particularly in well irrigated kiwifruit orchards with the synergistic effect of the above variables, the highest reduction of plant species has occurred. The continuous herbicides application and the soil compaction are strongly correlated with the reduction of taxa while the long-term agricultural practices such as inorganic fertilizers and Cu-fungicides application have a negative impact on plant species diversity. Considering that plant species diversity in agroecosystems is an integral part of global biodiversity, the environmental impact of new established crops and their cultivation techniques must be taken into consideration for environmental sustainability.

Authors' Contributions

Vassilios Triantafyllidis: Conceptualization, Methodology, Investigation, Writing - Original Draft, Data Curation, Formal analysis, Validation, Writing - Review & Editing, Supervision.

Anastasios Zotos: Methodology, Investigation, Formal analysis, Data Curation, Validation, Writing - Original Draft, Writing - Review & Editing.

Kosma Chariklia: Investigation, Formal analysis, Data Curation, Validation, Writing - Original Draft.

George Kehayias: Data Curation, Writing - Review & Editing.

Pittaras Antonios: Investigation, Formal analysis, Writing - Original Draft.

Panagiotis Drougas: Investigation

REFERENCES

Ballabio, C., P. Panagos, E. Lugato, J. H. Huang, A. Orgiazzi, A. Jones and L. Montanarella. 2018. Copper distribution in European topsoils: An assessment based on LUCAS soil survey. Sci. Total Environ. 636: 282-298.

Basile, B., M. Giaccone, C. Cirillo, A. Ritieni, G. Graziani, Y. Shahak and M. Forlani. 2012. Photo-selective hail nets affect fruit size and quality in Hayward kiwifruit. Sci. Hortic. 141: 91-97.

Becerra, A. T., G. F. Botta, X. L. Bravo, M. Tourn, F. B. Melcon, J. Vazquez, D. Rivero and G. Nardon. 2010. Soil compaction distribution under tractor traffic in almond (*Prunus amigdalus* L.) orchard in Almería España. Soil Tillage Res. 107: 49-56.

Carey, P. L., J. R. Benge and R. J. Haynes. 2009. Comparison of soil quality and nutrient budgets between organic and conventional kiwifruit orchards. Agric. Ecosyst. Environ. 132: 7-15.

Dimopoulos, P., T. Raus, E. Bergmeier, T. Constantinidis, G. Iatrou, S. Kokkini, A. Strid and D. Tzanoudakis. 2013. Vascular Plants of Greece: An Annotated Checklist. Berlin: Botanic Garden and Botanical Museum Berlin-Dahlem; Athens: Hellenic Botanical Society.

Dimopoulos, P., T. Raus, E. Bergmeier, T. Constantinidis, G. Iatrou, S. Kokkini and D. Tzanoudakis. 2016. Vascular plants of Greece: An annotated checklist. Supplement Willdenowia. 46: 301-347.

Ditzler, C., K. Scheffe and H. C. Monger. 2017. Soil Science Division Staff. Soil Survey Manual. USDA Handbook No. 18: 120-131.

Egan, J. F. and D. A. Mortensen. 2012. A comparison of land-sharing and land-sparing strategies for plant richness conservation in agricultural landscapes. Ecol. Appl. 22: 459-471.

FAOSTAT. 2021. Food and Agriculture Organization of the United States. Available from: https://www.fao.org/faostat/en/#data/QCL [Last accessed on 2021 Apr].

Fridley, J. D. 2003. Diversity effects on production in different light and fertility environments: An experiment with communities of annual plants. J. Ecol. 91: 396-406.

Gaba, S., R. Perronne, G. Fried, A. Gardarin, F. Bretagnolle, L. Biju-Duval and X. Reboud. 2017. Response and effect traits of arable weeds in agro-ecosystems: A review of current knowledge. Weed Res. 57: 123-147.

Getenga, Z. M. and F. O. Kengara. 2004. Mineralization of glyphosate in compost-amended soil under controlled conditions. Bull. Environ. Contam. Toxicol. 72: 266-275.

Heap, I. and S. O. Duke. 2018. Overview of glyphosate-resistant weeds worldwide. Pest. Manag. Sci. 74: 1040-1049.

Holmgren, M., M. Scheffer and M. A. Huston. 1997. The interplay of facilitation and competition in plant communities. Ecology. 78: 1966-1975.

Huang, H. and Y. Liu. 2014. Natural hybridization, introgression breeding, and cultivar improvement in the genus Actinidia. Tree Genet. Genomes. 10: 1113-1122.

Kosma, C., V. Triantafyllidis, A. Papasavvas, G. Salahas and A. Patakas. 2013. Yield and nutritional quality of greenhouse lettuce as affected by shading and cultivation season. Emir. J. Food Agric. 25: 974-979.

Lindsay, W. L. and W. A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42(3): 421-428.

Moore, A., S. Hines, B. Brown, C. Falen, M. de Haro Marti, M. Chahine, R. Norell, J. Ippolito, S. Parkinson and M. Satterwhite. 2014. Soil-plant nutrient interactions on manure-enriched calcareous soils. Agron. J. 106: 73-80.

Newbold, T., L. N. Hudson, S. L. Hill, S. Contu, I. Lysenko, R. A. Senior, L. Börger, D.J. Bennett, A. Choimes, B. Collen, J. Day, A. De Palma, S. Díaz, S. Echeverria-Londoño, M. J. Edgar, A. Feldman, M. Garon, M. L. K. Harrison, T. Alhusseini, D. J. Ingram, Y. Itescu, J. Kattge, V. Kemp, L. Kirkpatrick, M. Kleyer, D. Laginha Pinto Correia, C. D. Martin, S. Meiri, M. Novosolov, Y. Pan, H. R. P. Phillips, D. W. Purves, A. Robinson, J. Simpson, S. L. Tuck, E. Weiher, H. J. White, R. M. Ewers, G. M. Mace, J. P. W. Scharlemann and A. Purvis. 2015. Global effects of land use on local terrestrial biodiversity. Nature. 520: 45-50.

Palm, C., H. Blanco-Canqui, F. DeClerck, L. Gatere and P. Grace. 2014. Conservation agriculture and ecosystem services: An overview. Agric. Ecosyst. Environ. 187: 87-105.

Patriquin, D. G., H. Blaikie, M. J. Patriquin and C. Yang. 1993. On-farm measurements of pH, electrical conductivity and nitrate in soil extracts for monitoring coupling and decoupling of nutrient cycles Biol. Agric. Hortic. 9: 231-272.

Poschenrieder, C., J. Bech, M. Llugany, A. Pace, E. Fenés, J. Barceló. 2001. Copper in plant species in a copper gradient in Catalonia (North East Spain) and their potential for phytoremediation. Plant Soil. 230: 247-256.

PPDB. 2021. Pesticide Properties Database (PPDB). University of Hertfordshire, UK. Pesticide Properties Database. Available from: https://sitem.herts.ac.uk/aeru/ ppdb/en/index.htm [Last accessed on 2021 May].

Rhodes, R., N. Miles and J. C. Hughes. 2018. Interactions between potassium, calcium and magnesium in sugarcane grown on two contrasting soils in South Africa. Field Crops Res. 223: 1-11.

Sillanpaa, M. 1982. Micro Nutrients and the Nutrient Status of Soils. A Global Study. FAO Soils Bulletin, No.48, Food and Agriculture Organization, Rome.

Souza, A. D., P. S. L. Silva, O. F. Oliveira, I. M. Dantas and P. L. D. Morais. 2013. Weeds under the canopies of tree species submitted to different planting densities and intercropping. Plant. Daninha. 31: 29-37.

Ter Braak, C. J. 1987. The analysis of vegetation-environment relationships by canonical correspondence analysis. Vegetatio. 69(1-3): 69-77.

Ter Braak, C. J. and P. Smilauer. 1998. CANOCO Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power, Ithaca, NY, USA.

Thomas, G. W. 1982. Exchangeable cations. Methods of soil analysis.

Part 2. Chem. Microbiol. Prop. 9: 159-165.

Todd, J. H., L. A. Malone, B. H. McArdle, J. Benge, J. Poulton, S. Thorpe and J. R. Beggs 2011. Invertebrate community richness in New Zealand kiwifruit orchards under organic or integrated pest management. Agric. Ecosyst. Environ. 141: 32-38.

Triantafyllidis, V., A. Zotos, C. Kosma and E. Kokkotos. 2020. Effect of land-use types on edaphic properties and plant species diversity in Mediterranean agroecosystem. Saudi J. Biol. Sci. 27: 3676-3690.

Triantafyllidis, V., C. Kosma, A. Kontogeorgos and A. Patakas. 2018. An assessment of the soil quality index in a Mediterranean agro ecosystem. Emir. J. Food Agric. 30: 1042-1050.

Tutin, T. G., N. A. Burges, A. O. Chater, J. R. Edmondson, V. H. Heywood, D. M. Moore and D. A. Webb. 1993. Flora Europaea. Vol. 1, 5. Cambridge University Press, Cambridge, UK.

Wang, N., H. He, C. Lacroix, C. Morris, Z. Liu and F. Ma. 2019. Soil fertility, leaf nutrients and their relationship in kiwifruit orchards of China's central Shaanxi province. Soil Sci. Plant Nutr. 65: 369-376.

Yassoglou, N., C. Tsadilas, and C. Kosmas. 2017. Soil Classification. In the Soils of Greece. The Soils of Greece Springer International Publishing, New York, pp. 17-25.