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Ecological Factors Influencing the Occurrence of *Armillaria mellea* (Basidiomycota, Agaricales, Physalacriaceae) in Yuvacik Dam Watershed in Kocaeli, Türkiye

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Abstract: The occurrence of *Armillaria mellea* (Vahl) P. Kumm. and the ecological characteristics of this fungus were studied in Kocaeli, Yuvacik dam basin mixed-broad leaved forests**.** During the surveys, we analyzed the sporocarps (fruiting bodies) of *A. mellea* growing up on woody plants in plots selected by cluster sampling in the Yuvacik dam watershed dominated by broad-leaved forests. The Runs test results showed that randomness rules complied in the selection of the plots, and there was no tendency ($p= 0.109 > 0.05$, $z= -1.603$). The presence/absence of *A. mellea* and environmental variables were tested with Chi-square analysis, and the temperature differed among these environmental variables. To the dendrogram, *A. mellea* was mainly seen in the south of the study area and preferred western aspects. It is understood that this macrofungus prefers the south of the study area because of the altitude. Our data showed that sporocarps of *A. mellea* generally occurred in the western aspect, at temperatures of 15–20°C, >80% humidity and 800–1000 m altitude. Our logistic regression analysis model ($z=-9.508+0.307\times temperature+0.081\times humidity$) showed that if the temperature and humidity change by 1 unit in the region, sporocarp formation is affected by 36% and 8.4%, respectively.

Key words: *Armillaria mellea,* Sporocarp, Chi-square analysis, Logistic regression, Temperature, Humidity, Altitude

Yuvacık Barajı Havzasında (Kocaeli, Türkiye) *Armillaria mellea* (Basidiomycota, Agaricales, Physalacriaceae)'nın Oluşumunu Etkileyen Ekolojik Faktörler

Öz: Kocaeli, Yuvacık baraj havzası karışık-geniş yapraklı ormanlarında *Armillaria mellea* (Vahl) P. Kumm.'nın oluşumu ve bu mantarın ekolojik özellikleri incelenmiştir. Araştırmalar sırasında, geniş yapraklı ormanların hâkim olduğu Yuvacık baraj havzasında küme örneklemesi ile seçilen parsellerde odunsu bitkiler üzerinde yetişen *A. mellea* sporokarpları (fruktifikasyon organları) analiz edilmiştir. Runs testi sonuçları, parsellerin seçiminde rastgelelik kurallarına uyulduğunu ve herhangi bir eğilimin olmadığını göstermektedir ($p= 0.109 > 0.05$, $z= -1.603$). *A. mellea*'nın varlığı/yokluğu ve çevresel değişkenler Ki-kare analizi ile test edilmiş ve sıcaklık bu çevresel değişkenler arasında farklılık göstermiştir. Dendrograma göre *A. mellea* daha çok çalışma alanının güneyinde görülmekte ve batı bakıyı tercih etmektedir. Bu makrofungusun çalışma alanın güneyini tercih etmesinin sebebinin ise yükseklik olduğu anlaşılmaktadır.

Verilerimiz, *A. mellea* sporokarplarının genel olarak batı bakıda, 15-20°C, >80 % nemde ve 800-1000 m yüksekliklerde bulunduğunu göstermektedir. Elde ettiğimiz lojistik regresyon analizi modeli (z=-9.508+0.307×temperature+0.081×humidity), bölgede sıcaklık ve nem 1 birim değişirse sporokarp oluşumunun sırasıyla %36 ve %8.4 oranında etkilendiğini göstermektedir.

Anahtar kelimeler: *Armillaria mellea*, Sporokarp, Ki – kare analizi, Lojistik regresyon, Sıcaklık, Nem, Yükseklik

Introduction

The genus *Armillaria* (Basidiomycota, Agaricales, Physalacriaceae) are natural components of the mycoflora in many forests worldwide. They occur worldwide in boreal, temperate, and tropical forests, and through diverse parasitic activities, they influence many host species. The genus *Armillaria* is, therefore, significantly considered in the ecology and management of many natural forests (Kile et al., 1991). It also has a long and controversial taxonomic history. This discussion goes back to the Danish botanist Martin Vahl's description of *Agaricus melleus* (syn: *Armillaria mellea*) in 1787. Many taxonomic revisions have subsequently been published addressing the controversial genus name. *Armillaria* Fr. Staude is now the broadly accepted generic name with *Armillaria mellea* (Vahl) P. Kumm. (honey mushroom) (Balmantarı) representing the type of the genera. (Volk & Burdsall, 1995; Watling et al., 1982; Coetzee et al., 2018, Sesli et al., 2020). *A. mellea* was recognized as a mixture of at least 10 different "biological species" in the late 1970s (Hagle, 2010; Lushaj et al., 2010) and *A. mellea* sensu stricto is described as a pathogen in broadleaf and conifers (Kile et al., 1991; Guillaumin et al., 1993; Lushaj, 2008).

Among the seven species of *Armillaria* spread in Europe, six species are wood decay fungi with wide distribution and of great ecological and economical importance (Kile et al., 1991; Guillaumin et al., 1993; Lushaj, 2008). In the Balkan countries, seven species have been reported from Albania (Lushaj, 2008), six species from Slovenia and the Czech Republic (Munda, 1997; Jankovský, 2003), and five from Greece and Serbia (Tsopelas, 1999; Lushaj et al., 2010). There have been identified eleven species in Türkiye; *A. borealis* Marxm. & Korhonen (Kuzey balmantarı), *A. bulbosa* (Romagn.) Kile & Watling, *A. cepistipes* Velen.(Narin balmantarı), *A. gallica* Marxm. & Romagn.(Şiş balmantarı), *A. mellea*, *A. obscura* (Schaeff.) Herink (Top balmantarı) *A. ostoyae* (Romagn.) Herink (Külahlı balmantarı), *A. socialis* (DC.) Fayod (Yığın balmantarı), *A. solidipes* Peck, *Desarmillaria ectypa* (Fr.) R.A. Koch & Aime (Sivri balmantarı), and *D. tabescens* (Scop.) R.A. Koch & Aime (Sesli and Denchev, 2014, Sesli et al., 2020, Solak and Türkoğlu, 2022). *A. mellea* has been recorded on deciduous species such as *Quercus*, *Fagus*, *Castanea*, *Carpinus*, *Populus*, *Salix*, *Corylus*, and *Juglans* and coniferous species such as *Pinus*, *Abies*, and *Cedrus* in Türkiye (Selik, 1973; Sümer, 1977; Doğan and Öztürk, 2006; Türkekul, 2008).

In the life cycle of *Armillaria* species, basidiospores germinate on the woody substrate, and formed mycelium colonizes this wood tissue. Healthy trees are infected either by root contacts with infected woody tissue or by rhizomorphs growing out from the infected centre. *Armillaria* invades the root system and the lower stem of the infected trees, killing the cambium and causing heart rot. Sporocarps develop on dead/moribund wood tissue and release basidiospores into the environment (Heinzelmann et al., 2019). *Armillaria* overwinters as a mycelium or rhizomorph on the stems or roots of infected or dead trees. *Armillaria* overwinters as a mycelium or rhizomorph on the stems or roots of infected or dead trees. Rhizomorphs are black, branched, and filamentous structures that develop from spores and supply nutrient and air transmission (Selik, 1986; Baumgartner et al., Hagle, 2010; 2011;).

Most species of *Armillaria* are considered to be facultative necrotrophs that have parasitic and saprophytic phases. First, *Armillaria* colonizes the cambium of living roots (parasitic phase). Then, the fungus kills the cambium, causing a necrotic lesion beneath the root bark. Lastly, the fungus feeds on the dead tissue (saprophytic phase). This saprophytic capability makes *Armillaria* root disease so difficult to prevent (Baumgartner et al., 2011). Relatively few studies have focused on the distribution of the species, physical space factors, or stand type characteristics of the forest (Bruhn et al., 2000). *A. mellea* was associated with high pathogenicity in deciduous and coniferous except for pines in alkaline soils in England and observed that it grows rhizomorphs under soil over short distances (Rishbeth, 1982). Termorshuizen and Arnolds (1994) pointed out that host preferences of *Armillaria* species may be affected by soil type and their virulence may be related to tree vitality affected by soil type. It was detected on broad-leaved hosts growing on clay and loess soils in The Netherlands. It was recognized as a dominant parasite on broadleaved forests and fruit trees, especially in warm regions in the Czech Republic (Jankovský, 2003). This species was identified in deciduous and coniferous forests below 1100 m altitude in Greece (Tsopelas, 1999). *A. mellea* was determined on oaks between 700–1050 m altitude in Serbia (Keča et al., 2009), while on a few broadleaved and conifers species, below 1200 m in Albania (Lushaj et al., 2010). It was a species with low frequency in Poland (Łakomy, 2006) and the Ukrainian Carpathians (Tsykun et al., 2012).

Macrofungi studies in Turkey focused on its biodiversity rather than the ecological characteristics of fungi. There are a few papers based on this framework in our research area (Akata et al. 2018; Doğan et al., 2021). Yuvacik dam watershed, is located east of the Marmara region and in the transition zones of the three phytogeographic regions. The study area consists predominantly of pure and mixed broadleaved trees and mixed stands of deciduous and coniferous trees. *A. mellea*, which may attack deciduous and coniferous species, has been identified in previous studies in the research area. The present study aims to find out the ecological characteristics of *A. mellea* in the Yuvacik dam watershed area. We compared the presence/absence status of *A. mellea* to various environmental parameters in the sampled plots and analysed them with logistic regression.

Material and Metod

Study Area

Yuvacik dam watershed is located in the east of the Marmara region and the south of the Izmit district of Kocaeli province. It is coordinated at 40°32‟ N and 29° 58‟ E and covers 25.759 ha (Fig. 1 (Google Earth, 2022)).

The Yuvacık Dam is fed by three main streams, numerous creeks and the Hüseyinli pond, which is used for irrigation. The average altitude of the area varies from 170-1300 m (Beşkardeş, 2012; Efe et al., 2013).

The study area is in the transition zones of the three different phytogeographic regions including the Euro–Siberian (Sub–Euxine, underside section), the Mediterranean (the Aegean, underside section), and Irano–Turanian (the side of the inner Anatolia). In the watershed, the predominant forest tree species are *Fagus sylvatica* subsp. *orientalis* Lipsky, *Quercus* species, *Carpinus betulus* L., *Pinus nigra* Aiton, *P. sylvestris* L. and *Abies nordmanniana* subsp. *equi-trojani* (Asch. & Sint. ex Boiss.) Coode & Cullen). In addition, some other species are also found, such as *Castanea sativa* Mill., *Corylus avellana* L., *Alnus glutinosa* (L.) Gaertn., *Populus tremula* L., and *Juglans regia* L. in the area. Forests are made up of pure stands as well as mixed stands of these particular species (Beşkardeş, 2012; Efe et al., 2013). To the Thornthwaite methodology, the annual average precipitation and temperature are 1038.7 mm and 9.5 °C, respectively. The study area has a climate model that reflects similar oceanic climate parameters such as humidity, mild temperature and no water shortage (Zengin et al., 2005). The prevailing soil type is eutric cambisol and orthic luvisol in the FAO system (FAO 2022).

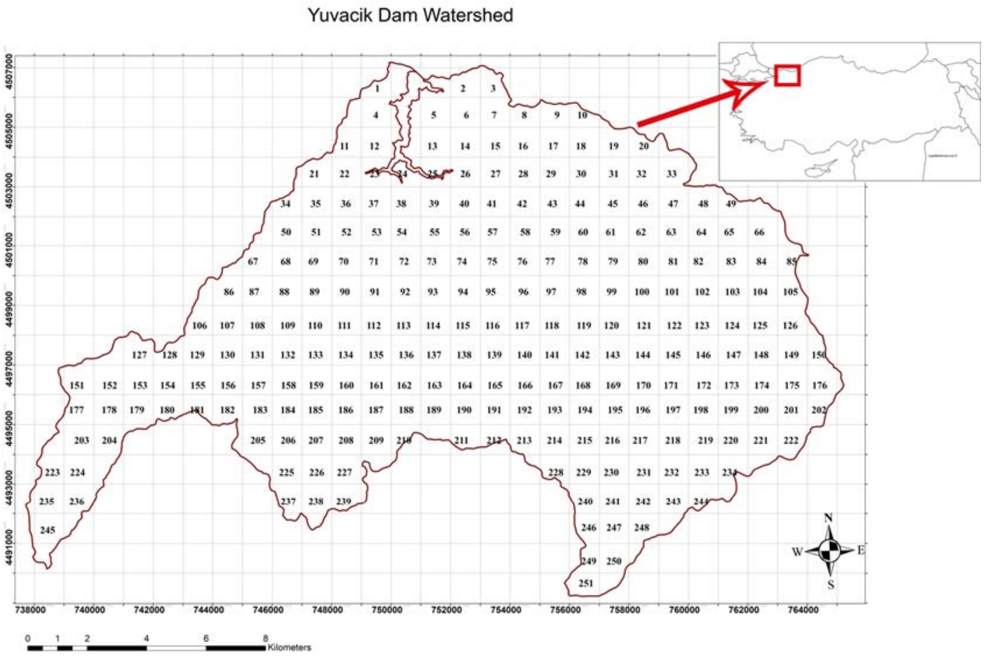

Figure 1. Location of Yuvacik dam watershed in the Marmara Region

The cluster sampling method was used in the Yuvacik dam watershed, spread over a 25759 hectar wide geographical area. The study area was divided into plots of 1 km² (grids) and 251 plots were obtained. 30 of 251 plots which correspond to approximately 12% of the study area were selected by simple random sampling (Fig 2). In our research, the transect method used 4 parallel transect sections running across plots of 1 km^2, 200 m apart as sampling patterns.

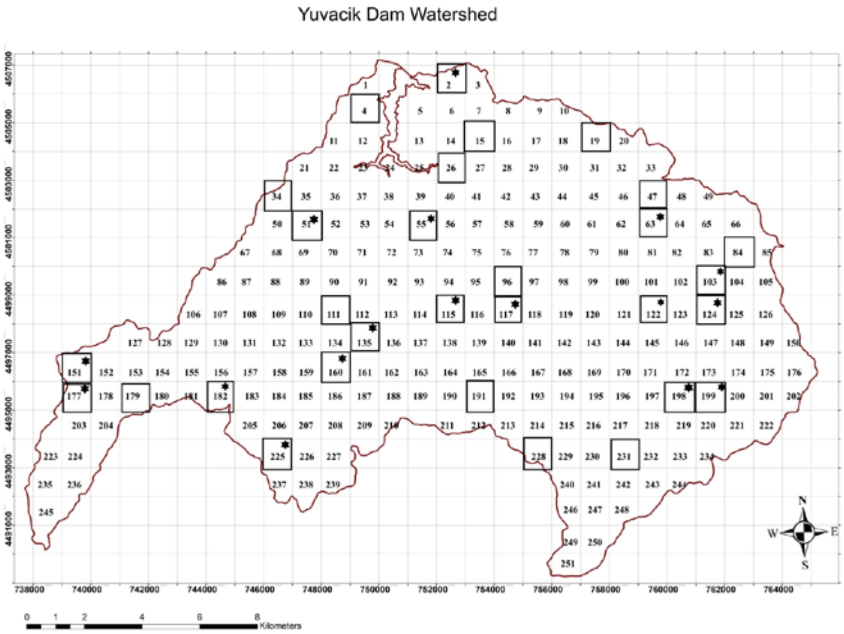

Figure 2**.** 30 sampled plots in the Yuvacik dam watershed (*where *Armillaria mellea* occurs)

Fungal Survey

Field surveys were systematically conducted during the vegetation season for symptomatic hosts and *A. mellea* sporocarps. Fallen and living trees, shrubs and stumps were examined in four parallel transects, each 1 km in length. Whenever sporocarps were encountered on a plot, at least one individual mushroom was collected from genets representing each morphology type. The photographs were taken in their habitat. During the field studies, environmental variables of the sampled plots such as stand type, age class, tree species, crown closure, aspect, altitude, temperature, and air humidity were noted (Table 1). Microscopic characteristics of sporocarps specimens were examined using a Bresser light microscope. The measurements of at least 25 spores per specimen were taken. Identification was made from the relevant literature (Breitenbach and Kränzlin, 1991). Collected specimens turned into fungarium specimens and preserved in the cabinets by İZT-391 (3828) numbering at Poplar and Fast-Growing Forest Trees Research Institute, Kocaeli.

Statistical analysis

The Runs Test was performed to control whether the field study was on randomly selected plots. Chi-square analysis was used to determine whether there was a relationship among environmental variables in plots where *A. mellea* was observed. Hierarchical cluster analysis was performed considering ecological similarities and differences among plots. Besides, a dendrogram was created to show the similarity of the plots according to the environmental variables. In this paper, to find out the correlation between a set of independent variables such as temperature (°C), humidity (%), altitude (m), age class, and crown closure and the binary dependent variable with two possible values (presence=1/absence=0) logistic regression analysis was performed (Küçüker et al., 2010).

$$P(Y) = \frac{e^{z}}{1+e^{z}} \rightarrow P(Y) = \frac{1}{1+e^{-z}}$$

z is a linear combination of independent variables.

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$$

β_0, β_1, β_2,...+ β_n are regression coefficients. The calculation of the regression coefficients is as follows:

$$\ln\left(\frac{P(Y)}{Q(Y)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$$

$$\frac{P(Y)}{Q(Y)} = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots\cdots + \beta_n X_n} = e^{\beta_n X_n}$$

$$Q(Y) = 1 - P(Y)$$

The odds of an event occurring are calculated as the ratio of the probability of the property being present compared to the probability of it being absent. Odds= (P(Y))/(1-P(Y)) Which means, the Exp (β) value of each parameter is considered as the odds ratio. Exp (βi) values indicate to what extent the dependent variable Y is more likely to be observed with the effect of the variable X_i (Akalp, 2016).

Table 1. Sampling plots, hosts and environmental variables of *Armillaria mellea*

Plot No	Pre/Abs (1/0)	Coordinates	Altitude (m)	Slope (°)	Temperature (°C)	Humidity (%)	Aspect*	Host**	Colonization Site	Age Class***	Crown Closure****
2	1	36T/4506955-754968	537	31	13	81	NE	OK	Collar	BC	2
4	0	35T/4505440-749692	341	46	9	79	N	-	-	BC	2
15	0	35T/4504656-753915	612	24	8	84	S	-	-	BC	2
19	0	36T/4504596-757176	789	26	10	78	SW	-	-	BC	2
26	0	35T/4503521-752445	187	17	5	68	SE	-	-	BC	2
34	0	35T/4502608-746524	645	10	6	81	SW	-	-	BC	2
47	0	36T/4502324-759452	1012	23	6	77	SW	-	-	BC	2
51	1	35T/4501076-747851	459	26	12	77	N	OK	Collar	BC	2
55	1	36T/4501924-751604	587	10	8	74	NE	OK	Collar	BC	2
63	1	36T/4501672-759596	898	29	6	78	SW	OK	Stump	BC	2
84	0	36T/4500908-762885	1167	19	7	85	W	-	-	BC	2
96	0	36T/4499536-754539	1119	9	7	75	SW	-	-	CD	3
103	1	36T/4499040-761978	632	19	8	79	NW	OK	Stump	BC	2
111	0	35T/4498488-748296	592	44	15	86	SW	-	-	BC	2
115	1	35T/4498827-752720	886	25	17	83	W	BE	Stump	CD	3
117	1	36T/4498396-754532	1120	10	18	86	NW	BE	Collar	CD	3
122	1	36T/4498164-759912	1261	15	17	77	SE	OK	Stump	BC	2
124	1	36T/4498496-761687	743	29	11	77	NE	BE	Stump	BC	3
135	1	35T/4497228-749676	1061	27	16	82	SW	BE	Stump	CD	3
151	1	35T/4496392-739216	1041	28	20	72	SE	BE	Stump	CD	3
160	1	35T/4496768-748156	843	26	16	81	W	BE	Stump	CD	3
177	1	35T/4495642-739516	903	16	17	78	SW	HBM	Stump	CD	3
179	0	35T/4495080-741356	842	27	15	67	W	-	-	BC	2
182	1	35T/4495496-744556	987	7	17	62	NE	HBM	Stump	CD	2
191	0	35T/4495584-753917	1186	7	14	55	E	-	-	CD	3
198	1	36T/4495726-760196	991	15	23	76	SE	OK	Stump	BC	2
199	1	36T/4495612-761875	900	23	15	81	E	OK	Stump	BC	2
225	1	35T/4493436-746768	1042	19	15	57	NW	OK	Stump	BC	2
228	0	36T/4493800-755480	975	18	12	60	SE	-	-	BC	2
231	0	36T/4493560-758760	850	8	16	56	SW	-	-	BC	2

*N: North, S: South, W: West, E: East, SW: Southwest, NW: Northwest, SE: Southeast
**OK: Oak, HBM: Hornbeam, BE: Beech
***a (0 – 8 cm), b (9 – 20 cm), c (21 – 36 cm), d (36 - 52 cm) Diameter at Breast Height (Age class)
****1 (11 – 4 %), 2 (41 – 70%), 3 (71 – 100%) Crown closure

To investigate whether environmental factors affect the presence of sporocarps of *A. mellea* in the plots, we analysed all variables together and removed the least expressive independent variable stepwise with Binary Logistic and Backward LR method on IBM SPSS Statistics 21 (IBM CR, 2012).

Results

According to the Runs test, there was no relationship between the presence of *A. mellea* and the selection order of the plots ($p= 0.109 > 0.05$, $z= -1.603$). Our results showed that randomness rules complied in the selection of the plots, and there was no tendency. *A. mellea* was detected in 17 of the 30 plots. This count represents 56% of the study area. All of the sporocarps of *A. mellea* were found on deciduous trees and particularly on stumps. 71% of plots, where *A. mellea* sporocarps occur were at an altitude of >800 m. Our determinations showed that they grew up mostly in the western aspect, "bc" age class and "2" crown closure. In addition, its sporocarps occurred in a high frequency at a temperature of 15–20 °C and >80 humidity (Table 1; Fig 3).

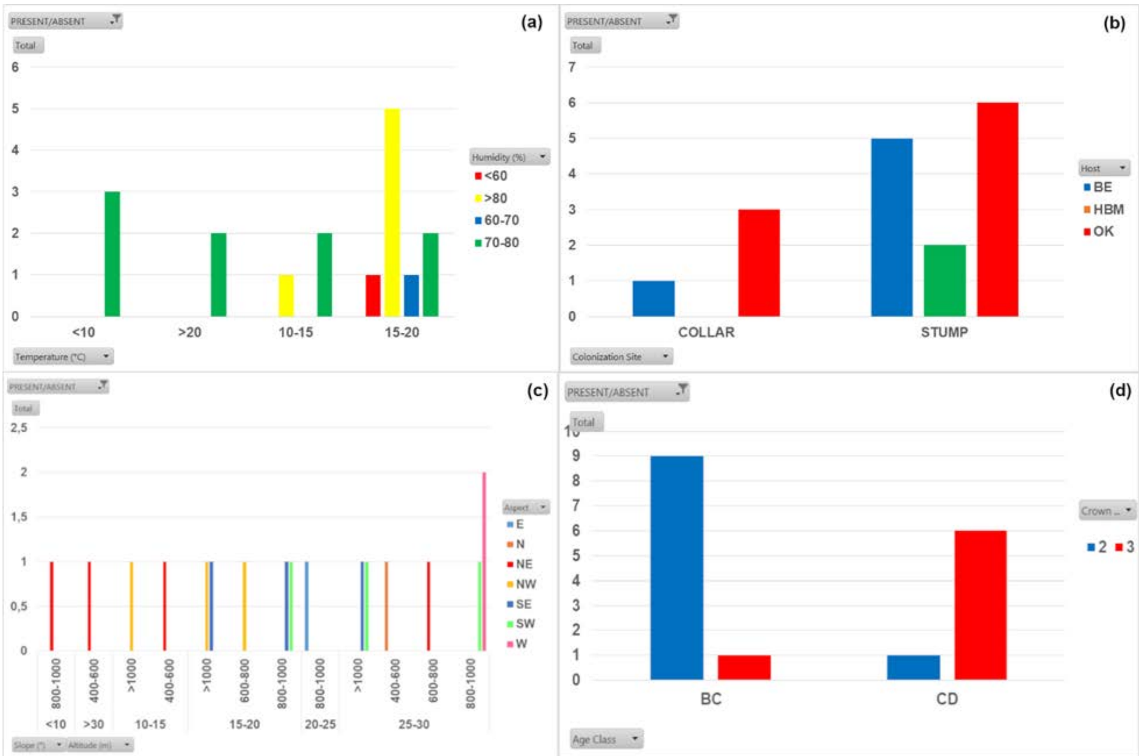

Figure 3. The effect of environmental variables on the occurrence of *Armillaria mellea* (a)Temperature–humidity, (b)colonization site-–host preference, (c)altitude–slope–aspect, (d)age class–crown closure

The presence/absence of *A. mellea* and environmental variables were tested with Chi-square analysis, and the results are given in Table 2. The temperature was different among these environmental variables, except for the host and colonization area. In addition, the graphical representations of these environmental variables were given in Figure 4. Environmental similarities and differences among plots where *A. mellea* was present and absence was determined by Hierarchical clustering analysis. In addition, a dendrogram showing the similarities of the plots was created for environmental variable groups in Figure 5.

The dendrogram consisted of 3 clusters including in order of 9, 12 and 9 plots from top to bottom and *A. mellea* was found on 6, 7, and 4 plots, respectively. To the dendrogram, *A. mellea* was mainly seen in the south of the study area and preferred western aspects. It is understood that this macrofungus prefers the south of the study area because of the altitude. In addition, *A. mellea* needed optimum conditions in terms of temperature and humidity; in other words, the probability of its occurrence decreases at high humidity and low temperature, as well as at low humidity and high temperature.

Table 2. Chi-square analysis of environmental variables, effect on the occurrence of *Armillaria mellea*.

Environmental Variables	**df**	**X²**	***p*-Value**	**Cramer's V**	**Effect Size**
Slope (°)	5	4.830	0.348>0.05 NS	0.401	Relatively Strong
Altitude (m)	4	4.457	0.437>0.05 NS	0.385	Moderate
Temperature (°C)	1	5.954	0.015<0.05 *	0.454	Relatively Strong
Humidity (%)	3	3.180	0.365>0.05 NS	0.326	Moderate
Aspect	7	8.824	0.366>0.05 NS	0.542	Relatively Strong
Age Class	1	2.334	0.127>0.05 NS	0.279	Moderate
Crown Closure	1	2.334	0.127>0.05 NS	0.279	Moderate
Host	4	10.168	0.038<0.05 *	0.550	Relatively Strong
Colonization Site	3	22.961	0.000<0.001 ***	0.875	Very Strong

NS: Non-significant, *correlation is significant at the 0.05 level

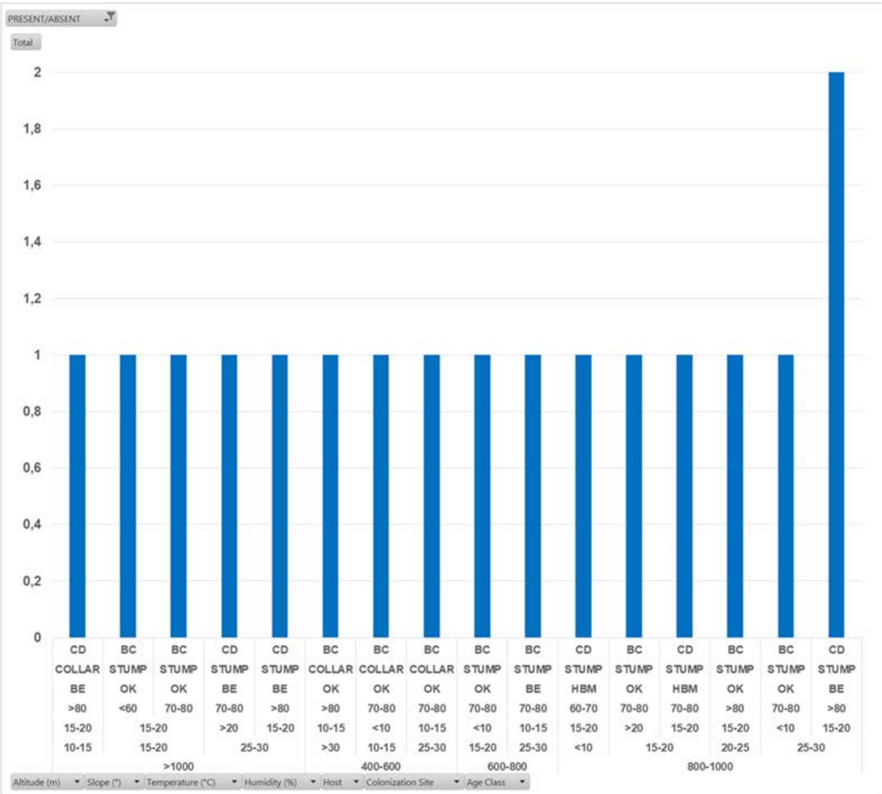

Figure 4. The relationship between environmental variables and *Armillaria mellea* in Yuvacik dam watershed.
OK: Oak, HBM: Hornbeam, BE: Beech, a (0–8 cm), b (9–20 cm), c (21–36 cm), d (36-52 cm)
Diameter at Breast Height (Age class); 1 (11–4 %), 2 (41–70%), 3 (71–100%) Crown closure

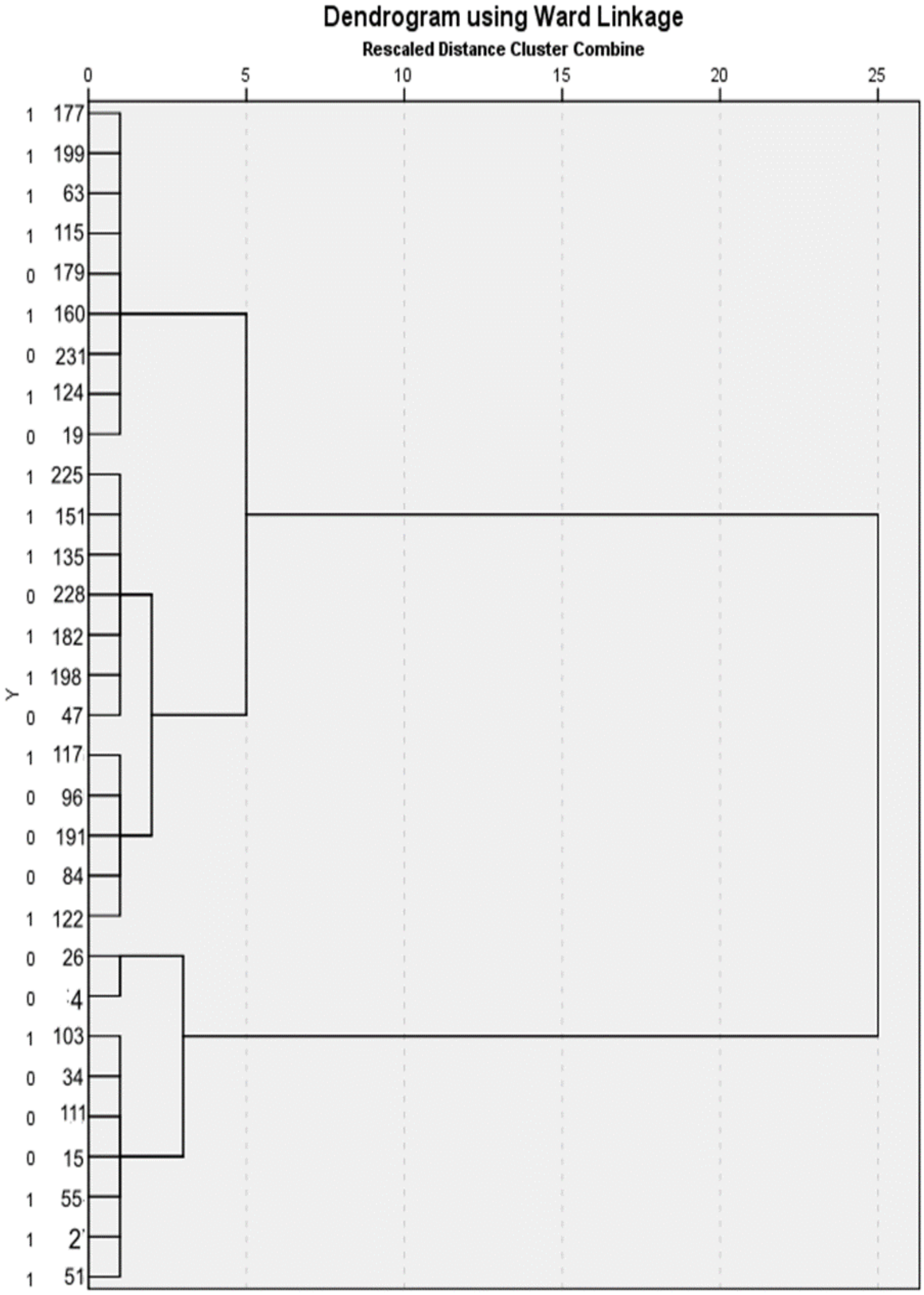

Figure 5. The clustering of the plots according to the presence/absence of *Armillaria mellea* for environmental variable groups in the study area.

It was investigated whether there is an effect of temperature (°C), humidity (%), altitude (meters), age class and crown closure on the presence of sporocarps of *A. mellea* in the plots. To create a new model using the Binary Logistic and Backward LR method, the age class, crown closure and altitude variables were removed from the model at the last step (Step 5). In terms of significance levels, positive advantages and Exp (B) values, the temperature (°C) and humidity (%) variables remained in the model, and the following statistically significant model was created.

$$z = -9.508 + 0.307 \times \text{temperature} + 0.081 \times \text{humidity}$$

In step 5 of Table 3, we found that the temperature affects the occurrence of sporocarps of *A. mellea* 1,36 times (36%). In other words, when the temperature is altered by 1 unit, sporocarps' probability of occurrence is affected by 36% (e^0.307). Furthermore, the humidity alteration affects the presence of sporocarps of *A. mellea* by 8.4% (e^0.081). In the new model, when the ratio of the relevant independent variables is included in the model, the probability ratio of the dependent variables (P(Y)) is obtained. If P(Y) is >0.5, we estimate that *A. mellea* is found in the area.

Table 3. Logistic regression analysis and estimated logit coefficients, the effects of the environmental variables on the occurrence of *Armillaria mellea* sporocarps.

Variables in the Equation							
Steps- Variable		Estimated Logit Coefficient	Standard Error	Wald	df	Significance Level	Exp(B)/Odds Ratio
Step 1[a]	altitude	-.001	.002	.352	1	.553	.999
	slope	-.084	.071	1.388	1	.239	.919
	temperature	.382	.164	5.413	1	.020	1.465
	humidity	.121	.069	3.060	1	.080	1.128
	age class	.830	1.980	.176	1	.675	2.294
	crown closure	-1.153	1.725	.447	1	.504	.316
	constant	-10.140	6.273	2.613	1	.106	.000
Step 2[a]	altitude	-.002	.002	.411	1	.521	.998
	slope	-.072	.064	1.295	1	.255	.930
	temperature	.358	.149	5.765	1	.016	1.430
	humidity	.116	.067	3.037	1	.081	1.124
	crown closure	-.646	1.220	.280	1	.597	.524
	constant	-9.459	5.804	2.656	1	.103	.000
Step 3[a]	altitude	-.001	.002	.243	1	.622	.999
	slope	-.073	.063	1.318	1	.251	.930
	temperature	.366	.146	6.320	1	.012	1.442
	humidity	.120	.066	3.331	1	.068	1.127
	constant	-10.635	5.429	3.837	1	.050	.000
Step 4[a]	slope	-.060	.058	1.076	1	.300	.942
	temperature	.344	.138	6.192	1	.013	1.410
	humidity	.119	.066	3.264	1	.071	1.127
	constant	-11.478	5.285	4.716	1	.030	.000
Step 5[a]	temperature	.307	.121	6.429	1	.011	1.360
	humidity	.081	.051	2.511	1	.113	1.084
	Constant	-9.508	4.570	4.329	1	.037	.000
a. Variable(s) entered on step 1: altitude. slope. temperature. humidity. age. crown.							

Discussions

To chi-square results, the presence of *A. mellea* is independent of the slope, altitude, humidity and aspect, age class and crown closure variables, but it is dependent on temperature, host and colony location variables. *A. mellea* was specified mostly at an altitude of >800 m while it was not seen above 1200 m in the present study. This finding is consistent with previous studies conducted in Europe (Guillaumin et al., 1993; Tsopelas, 1999; Keča et al., 2009; Lushaj et al., 2010; Mesanza et al., 2017).

In this survey, all of the sporocarps were found on broad-leaved trees. It was recorded on deciduous trees by previous studies in the Netherlands, Greece, Czech Republic, Serbia, Albania, and Spain (Termorshuizen and Arnolds, 1994; Tsopelas, 1999; Jankovský, 2003; Keča et al., 2009; Lushaj et al., 2010; Mesanza et al., 2017).

In our study, sporocarps were mostly found on the root collars of living trees of oak and beech, and stumps in the western aspect. Mesanza et al. (2017) observed *Armillaria* species mostly in the western aspect of Spain. Also, they mainly found sporocarps on the root collars of dead and living trees and stumps. Our determinations showed that *A. mellea* grew up in the "bc" age class and "2" crown closure. Dálya et al. (2019) evaluated the presence and distribution of root rot fungi in the Vallombrosa (Italy) forest after severe storm damage. They noted that *A. mellea* grew between 20–60, according to the age classes of forest stands. Our findings are similar to the study results of Dálya et al. (2019).

A. mellea is widely spread in the presence of an Atlantic climate as in England, part of France and the Mediterranean climate in Italy, Portugal and Spain (Guillaumin et al., 1993). In our study, we found out that the optimum temperature was 15–20 °C and humidity >80 humidity (%) for the growth of the sporocarps of the species. Guillaumin et al., (1993) reported that *A. mellea* is a thermophilic species of Atlantico-Mediterranean distribution. Keča (2005) reported that the fastest growth was at 22 °C in his study of mycelium development on five *Armillaria* species, including *A. mellea*. Hasegawa et al., (2011) showed that *A. mellea* was thermophilic according to Kira's warmth index (WI) and indicated a very similar thermal preference between Europe and Japan.

In addition, the dendrogram showing the similarities of the plots was created for environmental variable groups by hierarchical clustering analysis. We also provided the knowledge that the occurrence of *A. mellea* decreased both at high humidity and low temperature or low humidity and high temperature. In other words, the sporocarps of *A. mellea* prefer optimum conditions of temperature and humidity.

The results of logistic regression analysis revealed that temperature affects the growth of the sporocarps of *A. mellea* by 36%. When the temperature varies by 1 degree, the growth of the sporocarps is affected 1.36 times. This rate is 8.4% for humidity. This logistic regression equation can be used to predict *Armillaria*'s prevalence in this study area.

Armillaria has not been reported as a major epidemic or disease agent for the study area so far. However, there are significant losses in the world, especially in terms of oak species. It is required to observe *A. mellea*, which can be a substantial threat to deciduous and coniferous species. Our results show that the sporocarps of *A. mellea* grow on stumps by 80%. This detection indicates that the species is currently saprophytic in the area and reveals that treatment of stumps should be attentive to avoid an epidemic caused by *A. mellea* in the future.

A. mellea is the most virulent species of broad-leaved forests and has caused significant economic losses in western Europe. However, *Armillaria* species are thought to be beneficial for the carbon cycle in natural ecosystems as a saprophytic, especially white–rot. It is also used in the food and pharmaceutical industry. It is a requirement to realize regular surveys in the field for a species that is considered to have such different effects. There is little knowledge of *Armillaria*'s diversity, distribution, pathogenicity, pandemic, and virulence in the forest of Türkiye. The species diversity of the *Armillaria* complex should be investigated and supported by molecular methods. It is required to give importance to the pathogenicity, virulence, and pandemic risk analysis studies of *Armillaria* species in Türkiye forests. Since the incidence of *A. mellea* is higher in the “bc” age class and “2” crown closures in the study area, it is revealed that more attention should be paid to sites with this feature in terms of epidemics in forestry studies. In addition, our findings support that this fungus commonly affects younger individuals. Studies on assessment as a non–wood forest product (in the food and pharmaceutical industry) maybe provide significant knowledge of the environmental requirements of these species.

Author contributions

Sabiha Acer coordinated the research, planned and carried out the identifications and discussed the results. Ersel Yilmaz developed the theory and analytical methods, conducted the field experiment, and run the data analysis. Ayhan Karakaya supervised the work, designed and conducted the field experiment, and discussed the results. All authors helped in writing, read, and approved the final manuscript.

Conflicts of interest

The authors declare no competing interests.

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