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The effects of different soil substrates and potassium applications on Chickpea (Cicer arietinum L.) some plant yield and membrane permeability under dry conditions

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Abstract

This study was conducted as a pot experiment potassium fertilizer different doses effects were investigated plant growth and membrane permeability on chickpea plants in dry conditions. The experiment was designed as a randomized block design with 3 replications. The 18 pots were composed of two different textures as 1:1 peat+soil and only soil in the experiment. Three different doses of potassium fertilizer (Control: 0ppm K, 100ppm K, 200ppm K) were given with seed sowing. The chickpea plants were harvested at the end of 8 weeks and results were evaluated. Plant dry matter yield was found between 19.60g/pot and 52.25g/pot. As applied potassium fertilizer dose has decreased plant root and leaf dry matter yield has also decreased when potassium doses increased these values have increased. Peat+soil mixture texture has supported plant growth. The effect of potassium fertilizer on plant growth and membrane permeability was found statistically significant ($p<0.05$). Membrane permeability values were decreased as the amount of applied potassium doses increased. The highest membrane permeability was obtained from 0ppm K and only soil texture group with 48.4%. In this application, the cell membrane has been damaged at the highest level. The lowest membrane permeability value was obtained from 100ppm K and peat+soil mixture texture with 18.6%. As a result of this study, it was determined that organic matter contains texture supported plant growth and K fertilizer especially protected chickpea plant from water stress under dry conditions.

Keywords: Peat+soil, potassium, fertilization, membrane, growth.

1. INTRODUCTION

Agricultural production is carried out under difficult conditions in arid and semi-arid regions. Rainfall and lack of nutrients are very important in plants grown in these regions. If we try to remedy these stress conditions with some applications, we will provide suitable conditions for the growth of plants and increase of yield. In terms of plant nutrition and fertilization, potassium is a plant nutrient that regulates the water level in plants. Potassium element increases root growth in plants and improves stress conditions. Potassium also increases the fixation of nitrogen by promoting root development in plants. Abdalla and Abdelwahab (1995), as a result of the study of the element in the plant, the water level of potassium in the plant body and roots have found that increase the yield of dry matter.

Chickpea is one of the first plants to be cultured over the world. As a gene center, Turkey has been shown to be located in the Eastern Mediterranean region. Dry grains contain a high percentage of protein (15-32%) and carbohydrates (50-74%), as well as minerals such as phosphorus, calcium and iron, and rich in A, B and Niacin vitamins (Smithson et al.1985). Chickpea plants are most resistant to drought and low heat take placed the second legume after red lentil. It is not very selective in terms of soil demand. Drainage is well, slightly acid or alkaline reaction, limestone and arid soils are grown. It is resistant to drought due to its small vegetative parts and pile root system. It increases its agricultural importance. In this form, cereal-fallow is one of the few plants in the rotation system (Azkan, 1989; Isik, 1992; Sepetoglu, 1994).

Plants need nutrients to growth. They take most of their nutrients from the soil by their roots. Fertilization should be done if there are insufficient nutrients in the soil for the plant to grow. Nutrients that are missing in soil should be given to soil in order to obtain high quality products in agricultural production. The most effective breeding process for the yield and quality of plants is fertilization (Ertekin et al., 2020; Ertekin et al., 2022). However, excessive fertilization should be refrained (Aygün and Mert, 2021).

Water needs provided for the plant nutrients to be effective. In some regions of our country, agricultural production is continued without irrigation and fertilization. Water needed in agricultural production is provided from rain water in semi-arid climate conditions (Bellitürk et al., 2019).

In the world, 12.7 million hectares of chickpeas are cultivated and 12.1 million tons of products are obtained from this area. The world average yield is 95.6 kg per decare (FAO 2016). Among the legumes in our country, chickpea takes the first place with 359 thousand ha cultivation area and 460 thousand tons production, while it is 224 thousand ha cultivation area and 360 thousand tons production of lentils. (Red-green) and is followed by dry bean planting area of 94 thousand hectares and 235 thousand tons. The yields of these products are respectively 128, 286 and 251 kg (TUIK, 2016). Sangakkara et al. (1996), the environmental effects of stress, and especially the negative effects of water stress on plants, can be reduced by potassium fertilization can be reduced and as a result of their research in leguminous plants, potassium fertilization, the body and roots in the amount of dry matter caused by the increase in the amount of water and negative effects of stress reported.

Alpaslan and Güneş, (2001) reported that the salt stress and boron toxicity they applied to the tomato and cucumber plants they grow caused a decrease in the amount of dry matter in the stem and roots. Under the same conditions, they stated that these stress conditions increased membrane permeability and that boron application under salted conditions had no effect on membrane permeability. Inal and Tarakçıoğlu (2001), as a result of the application of ammonium, as per a result of ammonium application, membrane permeability values of 30%, as a result of application of urea as a result of mixed application of 25%, as a result of mixed application of 25% and 27% as a result of nitrate application. Kaya et al. (2001), the cultivated tomato plant, a high level of NaCl application, a significant decrease in the amount of dry matter was observed. Potassium and phosphorus application increased the amount of dry matter in the stem and stem. While membrane permeability value increased with high NaCl application, it was determined that membrane permeability decreased as a result of application of potassium and phosphorus to plants.

Liang et al. (2001) found that toxic application of barley plant to aluminum increases the permeability of membrane. At the same time root length of the plants, dry matter yield in the root and stem, nitrogen and phosphorus concentrations in the plant body and nitrogen and potassium concentrations in the root decreased. Kaya et al. (2002), in vegetables grown under salt and alkali conditions, membrane permeability, while increasing the dry matter yield was determined to decrease. They concluded that saline conditions reduce water use and increase alkaline conditions. They obtained low dry matter content at high pH. Dry matter and chlorophyll formation were higher in pepper plant than tomato and cucumber. Kaya et al. (2003), high NaCl grown in the strawberry plant in the amount of dry matter, fruit yield and chlorophyll concentration was lower than control. It was observed that the negative effects of salt conditions on plant growth and fruit yield decreased in the subject applied calcium nitrate and potassium nitrate. In saline conditions, membrane permeability increased.

Kırnak et al. (2003), pepper plant nitrogen application, mulch and water stress, to investigate the effects on yield and quality; in their studies, they applied nitrogen at doses of 70, 140 and 210 kg / ha; found that water stress increases membrane permeability value and decreases nitrogen, phosphorus, potassium, calcium and magnesium concentrations in plant leaves. As a result of mulch application, water use efficiency increased by 12% compared to the control subject and fruit yield, fruit size, dry matter amount and chlorophyll concentration increased. Within the scope of sustainable agriculture, natural origin soil conditioners are used to achieve high efficiency in agricultural production (Aygün and Mert, 2020). Peat is a natural medium material which can be used for all kinds of plant breeding. It is a material with high ventilation capacity and at least 30% organic material. Organic fertilizers increase the content of organic matter in the soil and this means it can be increase of soil fertility and quality.

In this study, it was aimed to determine the effects of potassium fertilizer applied on soil and peat + soil mixture environment on growth development and membrane permeability in chickpea plant. It is known that potassium increases the resistance against drought and affects the yield positively. In order to increase the yield in areas with low rainfall, the possible effects on membrane permeability and potential increase in yield of potassium fertilizers were investigated.

2. MATERIAL and METHODS

This study was conducted as a pot experiment under dry conditions. Gökçe chickpea variety seeds were used as plant material. In the study, potassium sulfate fertilizer, peat, soil and pot was used as material.

Table 1. Soil analysis results

Soil Depth	pH	EC(%)	Organic matter (%)	Lime(%)	Texture
0-30cm	7.33	0.087	0,97	42	%20 sand %56 clay %24 loam

The study was designed with 2 repetitions and 3 replications according to the randomized block design. Pots with a capacity of 5 liters were filled with the peat and soil material mixed in 1:1. Fertilization subjects consist of control, 100ppm K application, and 200ppm K application. The study consisted of 18 pots with 6 subjects and 3 pots in each subject. 10 pieces of chickpea seeds were planted in each pot and 6 best plants were developed after the first true leaves were formed. Seeds were sown on 05.03.2019 and 30.04 .2019 and harvested 8 weeks later. Potassium Sulphate fertilizer was used as a source of potassium. Irrigation water has not been applied to the chickpea plant; it was grown under dry conditions. Rainfall is given in Table.2 between these dates.

Table 2. Total Rainfall between Sowing and Harvest Dates (kg/m^2)

Year	March	April
2019	38.7	47.1

In heavy rainy days, the plants were taken to the closed environment in order to prevent damage from rain water.

Trial topics:

T0: Soil culture in pot (unfertilized)

T1: Soil culture + 100 ppm K in pot

T2: Soil culture + 200 ppm K in pot

T3: Peat + Soil culture (unfertilized) in pot

T4: Peat + Soil culture + 100 ppm K in pot

T5: Peat + Soil culture + 200 ppm K in pot

Examined Properties and Methods

2.1. Determination of dry matter in the root and stem of the plant (g/pot):

After harvesting the plants, the root and body parts are separated from each other, washed with water and then washed with pure water for the last time. The results are expressed as g/pot. (Chapman & Pratt, 1982).

2.2. Determination of membrane permeability (%): From each plant, one young leaf sample was taken and fragmented 1 cm in size and shaken with pure water for 24 hours at 25 °C. As a result of this procedure EC_1 value was read and samples were taken at 1200ºC, after waiting 20 minutes, EC_2 value was read and membrane permeability was determined with $EC_1/EC_2 \times 100$ formula. (Lutts et al. 1996).

2.3. Statistical Analysis

The results were compared subjected to variance analysis (Açıkgöz et al. 1993).Statistically different means were grouped according to LSD (5%) test.

3. RESULTS AND DISCUSSION

3.1. Plant Dry Matter Yield (g/pot)

According to the results, relationship between dry matter yield and K fertilization were statistically significant at 5%. Table.3 shows that the average dry matter yield values in the plant body ranged from 19.60 to 52.25 g/pot. Cultivation environment has also positively affected plant growth. It is less or no rainfall in dates; potassium reduced the negative effects of water stress in chickpea plants.

Table 3. Average Plant Dry Matter Yield (g/pot)

Nutrition Treatments	Soil Culture	Soil+Peat Culture
Control	19.60c	30.17b
100ppm K	29.36b	42.23ab
200ppm K	41.66ab	52.25a
LSD(%5)	0.72	

In the study, the highest average yield values were obtained from the subject of T_5(Soil+Peat Culture+200ppm K) with 52.25g/pot and 42.23 g/pot with T_4(Soil+Peat Culture+100ppm K) and 41.66 g/pot with T_2 (Soil Culture+200ppmK) subjects. The lowest yield was found 19.60 g/pot from Control application. The effect of potassium fertilizer and mixture on dry matter yield was the same, peat and soil mixture media were found to be more successful than the control. It has been observed that negative effects of water stress can be reduced by potassium fertilization. This results supported to Mengel and Kirkby (1987), Abdalla and Abdclwahab (1995), and Sangakkara et al. (1995), Kaya et al. (2001).

3.2. Root Dry Matter Yield (g/pot)

As seen in Table 4, effects of peat mixture and potassium application on dry matter yield were found to be significant. As seen from Table 4, the dry matter yield values in the root ranged between 18.13 and 38.42 g/pot. In the study, the highest yield was obtained from T_5(Soil+Peat Culture+200ppm K) with 38.42 g/pot. The lowest yield was obtained from T_0 (control) with 18.13 g/pot. Root dry matter yield was low in only plants grown in soil environment. It is known that nitrogen fixation increases in leguminous plants grown in water stress as a result of potassium fertilization. With the increase of nitrogen fixation in the roots, root branching, growth and development are also has been observed.

Table 4. Root Dry Matter Yield (g/pot)

Nutrition Treatments	Soil Culture	Soil+Peat Culture

Control	18.13c	21.86b
100ppm K	22.72b	31.68ab
200ppm K	30.22ab	38.42 a
LSD(%5)	0.78	

(Kadıoğlu and Canpolat, 2019), in their study was conducted to determine the effects of plant growth promoting rhizobacteria on wheat and maize plant growth in different environments. According to the research results; when 100% pumice material increases dry root and stem weight and 100% peat material increases the number of bacteria. When the soil amount increased in the substrate/soil mixtures, dry root and stem weight and plant nitrogen, phosphorus and potassium content increased and the number of bacteria decreased.

(Ahmed, 2019) in wheat grown under salt stress conditions, increasing levels of salt application caused a statistically significant decrease in the green parts and root dry matter productions of the genotypes.

Similar results were obtained in this study. It can be said that potassium fertilization increases root growth in plants and hence also increases the dry matter yield in the root. The mixture of peat and soil increased branching in plant roots. The soil+peat texture has increased plant roots growth. Soil texture has been insufficient in terms of plant root development.

3.3. Membrane Permeability (%)

If the plant is exposed to stress conditions in the environment of the cell membrane is damaged and membrane permeability value increases. In this study, it was determined that membrane permeability values decreased in the conditions where the retention and water holding capacity of the growing environment were suitable. The effects of peat breeding medium on the development of chickpea and permeability were found to be significant.

Table 5. Average Membrane Permeability Values (%)

Nutrition Treatments	Soil Culture	Soil+Peat Culture
Control	48.4c	20.2a
100ppm K	43.7c	18.6a
200ppm K	32.6b	19.3a
LSD(%5)	1.18	

P>0.05 significant

Potassium fertilizer has less effected on membrane permeability than soil+peat mixture. This may be due to the fact that the plants did not have any stress conditions as they had sufficient water and ventilation conditions in the peat environment. In the study, the highest mean membrane permeability values were taken from control (T_0 group) with 48.4%. In this group, the cell membrane was damaged at the highest level.

The lowest membrane permeability was obtained from T_4 (Soil+Peat Culture+100ppm K) group with 18.6%. T_2 (Soil Culture+200ppmK) was found to be more successful than T_1 (Soil Culture+100ppmK) in membrane permeability. Although the data were close to the figures, they were statistically different. It can be said that potassium nutrients reduce the harmful effects of water stress on membrane permeability. As a result of water stress, salt stress and application of some elements to the researched plant, the value of membrane permeability was found to be increased (Liang et al. 2001).

(Ahmed, 2019), in wheat grown under salt stress conditions, it was observed that the average membrane permeability values of the varieties increased significantly due to the increased salt application.

4. CONCLUSION and SUGGESTIONS

In arid and semi-arid regions, plants are not able to supply enough water because they cannot supply enough water. Water stress is known to be the most important factor limiting agricultural production in arid and semi-arid regions. In this study, the effects of peat environment on the development of chickpea plant and cell membrane permeability were investigated with potassium fertilization. Potassium is a nutrient that promotes the use of water within the plant, so it may be advisable to apply it in arid regions, but the amount of potassium present in the soil should also be taken into account for this application.

The soils of Southeastern Anatolia are dense clay. For this reason, in the root developments of plants are occasionally negative. Mixing of these soils with organic material containing peat farm manure such as leonardite, and supporting it, can increase the productivity of the plant by providing positive growth. In semi-arid conditions, the use of peat materials is recommended in dry production enterprises.

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Evaluation of the forest quantity, quality and management through gray relational analysis method

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Abstract

Forests cover 30 per cent of the Earth's land surface, almost four billion hectares. They are necessary to sustain human health, economic growth and the environment. Also, approximately 25 per cent of the global population depends on forests for food and work. The world population is expected to reach 9.6 billion by 2050. Therefore, there needs to be quick action at all levels to make sure that forests are managed in a way that is good for the environment and our way of life in the future. The Sustainable Forest Management Goals are included in the major headings of Sustainable Development Goals and the United Nations Strategic Plan for Forests 2017–2030. The data for the worldwide and six geographical areas were assessed using the Gray Relational Analysis (GRA) approach, which is one of the Multi-Criteria Decision Making methodologies. The major goal of the study is to use the GRA mathematical approach to assess data from 6 geographical areas, totaling 245 regions and nations, and 236 countries and regions worldwide. The second purpose is to contribute to the existing literature by expanding the geographical scope, number of indicators, and the time period covered by the study. The study also aims to provide information on new forest quality and management technologies, as well as the change of geographical areas over 30 years. South America consistently comes out on top in interregional comparisons. On the other hand, Oceania ranks last in the rankings. While the scores for 1990 increased markedly for all regions and worldwide in 2000, the performance values for the years 2000, 2010 and 2020 are fairly close to each other. The findings and methods of this study are aimed to be a useful resource for future researchers and policymakers.
Keywords: monitoring and reporting, sustainable ecosystem, sustainable development goals, forest management, gray relational analysis, global forest goals, MCDM

Introduction

Forests are undoubtedly the richest biological diversity among terrestrial ecosystems. Forests not only serve people in economic, ecological, social and cultural aspects but also are the natural environments of plants, animals and other living creatures, which are essential part of the natural life. Forests supply fundamental ecosystem services, such as wood, food, non-wood goods and house, as well as soil and water protection and clean air. Forests stop soil degradation and desertification and decrease the danger of floods, landslides and snow slide, shortage of water, dust and sand storms and other disasters. Forests are home to almost 80 per cent of all terrestrial species. Forests mainly reduce climate change and ensure acclimatization and biodiversity (FAO, 2018). Although the factors that negatively affect the natural environment are generally considered as regional or local problems, the great effects of these factors are experienced globally. Therefore, forests and each tree need to be monitored and managed in a sustainable manner, in order to reach the Sustainable Development Goals (SDGs) and especially goals of SDG 15, which is particularly relevant for the sustainable management of forests. In order to emphasize that the forests are of great importance for people and all other living things, the UN General Assembly has determined March 21 as the International Forest Day, which is celebrated worldwide every year to create awareness and action plan on forest issues (Assembly, 2012).

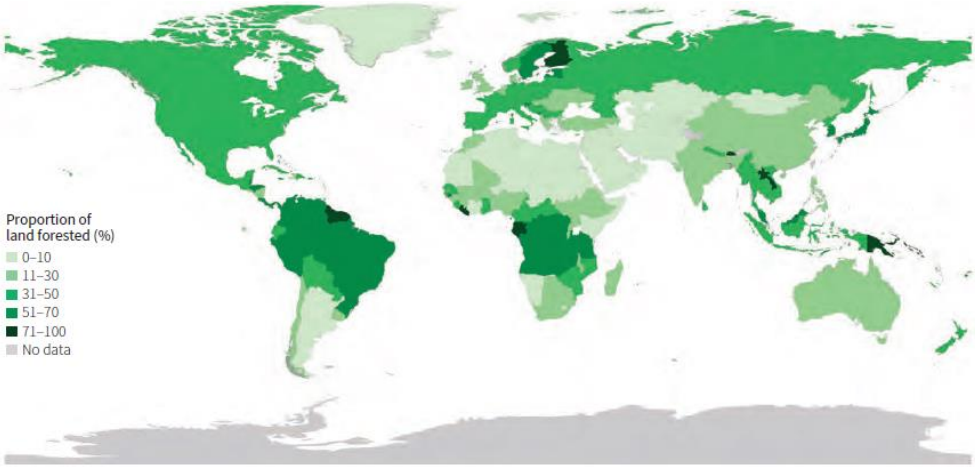

Figure 1. Forest area as a percentage of total land area, 2020 (FAO, 2020).

In recent years many agreements have been made such as the New York Declaration on Forests (NYDF), the Paris Agreement, the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs), and the UN Strategic Plan for Forests 2017-2030 (UNSPF) and its Global Forest Goals (GFGs). On the other hand, no significant progress has been made in solving global environmental issues despite all the efforts of international organizations, particularly the United Nations. The United Nations Strategic Plan for Forests 2017-2030 (UNSPF) presents a global plan for operations at all levels to sustainably manage all kinds of forests and trees and prevent forest degradation. The plan considers all forest-related frameworks and agreements for a sustainable environment and its vision is to supply economic, social, environmental and cultural benefits for present and future generations. UNSPF, in addition to 6 Global Forest Goals, has set 26 more goals planned to be reached by 2030 (Nations, 2017).

When making a selection, it's normal practice to look at a number of possibilities and choose the best one. It is necessary to choose the criteria that are relevant to the present situation. As a result, multi-criteria decision making (MCDM) is a technique that is extensively employed in forest management planning today (Kangas & Kangas, 2005). MCDM is used to tackle complex forest management difficulties because it combines the intuitive judgment operations of policymakers with logical knowledge management procedures (Ananda & Herath, 2009). When it comes to reviewing the forestry system, high-level decision-making procedures are required (Ok, Okan, & Yilmaz, 2011). Sustainability Forest Management (SFM) decisions are expected to be taken in order to meet the demands of society, the economy, and the environment. Efforts to employ GRA in forest management field have not applied in a global level. Çağlayan, Koç, and Demirel have a research on forest management in Turkey in collaboration with the Gray Relational Analysis (GRA). There are other city-country-specific analyses carried out using different methodologies within the MCDM framework. Many MCDM approaches, such as ELECTRE (Ok et al., 2011), TOPSIS (Stanujkic, Nikolic, & Stanujkic) AHP (Daşdemir & Güngör, 2010; Feng & Wang, 2000), AHP&TOPSIS (Nilsson, Nordström, & Öhman, 2016), GRA method (Çağlayan, Koç, & Demirel, 2017; Chan & Tong, 2007; Gai, Weng, & Yuan, 2011; P. Wang, Zhu, & Wang, 2016; Y. Wang et al., 2020; Zuxing & Dian, 2020) have been carried out in order to better understand the dynamics of forest management, quality and ecosystems. The fundamental objective of the research is to present the GRA mathematical approach in this field. The GRA's purpose is to assess the relationship between components based on the degree to which development patterns among these aspects are similar or different (Feng & Wang, 2000). The GRA technique has many significant benefits, the most important of which are that the conclusions are based on the original data and that the computations are basic and uncomplicated (Chan & Tong, 2007; Zhai, Khoo, & Zhong, 2009). In the study, a 30-year period analysis covering the past and present situations of the world and different geographical regions was conducted in achieving the sustainable forest management goals, which are included in the main headings of Sustainable Development Goals and the United Nations Strategic Plan for Forests 2017–2030.

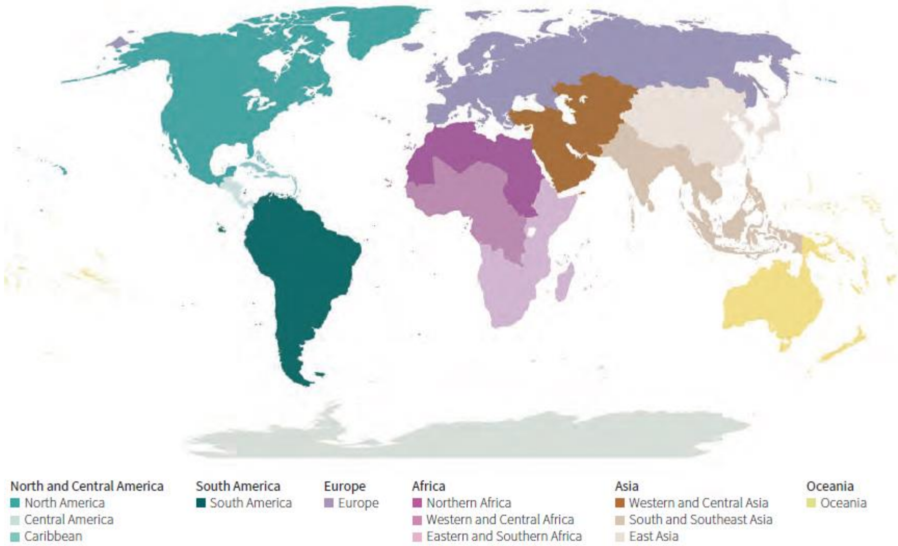

Figure 2. Regional and sub regional breakdown used in the Global Forest Resources Assessment 2020 (FAO, 2020).

In this study, the data of the World and 6 geographical regions were evaluated with the Gray Relational Analysis (GRA) method using 18 indicators related to forest quantity, quality and management in the Global Forest Resources Assessment 2020 Main Report. One of the primary aims of this study to evaluate the data of 6 geographical regions, including 245 regions and countries, with world-wide data belonging to 236 countries and regions, by using the GRA mathematical method. Also, performance assessment in models where many indicators have a positive and negative correlation with each other is evaluated using multi-criteria decision making approaches (Hasan, 2019; Hasan, Koçak, & Doğan, 2016). The reason of using this method is that, in GRA technique has been used for the assessment of forest quality and management in a variety of different geographical areas. The second goal of the research is to contribute to the literature by broadening the geographical scope, increasing the number of indicators, and extending the time period covered by the study. Providing information on new technologies for forest quality and management, as well as the evolution of the world's regions over a 30-year period, is another goal of the project.

The remaining of the study is organized as follows: Section 2 provides the research materials and methods. Section 3 summarizes the results, while Section 4 outlines the conclusions drawn from them.

2. Material and methods

The methodologies that were used in the research are described in this section.

2.1. Equal Weights Method

In order to determine the weighting method, it is necessary to have knowledge about the distributions of the actual weights. Sometimes there are situations where there is insufficient information to determine the weights. In such conditions, real weights can be explained as a uniform distribution on the n-unit simplex through the set {$0 \leq wj \leq 1$ and $\sum_{j=1}^{n} \boldsymbol{w}$; j=1,2,...n} (Jia, Dyer, 1998, 87-92). Therefore, within the framework of the hypothesis of insufficient or no knowledge about the weights, the distributions of the weights and their expected values are explained by the equal weights vector defined by Dawes and Corrigan as follows (Dawes, Corrigan, 1975, 95-106): wj = 1/n j = 1,2....,n (n: number of qualifications). In line with this information, the method of equal weighting has been applied to the qualifications in the study.

2.2. Gray Relational Analysis (GRA) Method

The gray relational analysis (GRA) method was proposed by Ju-Long (1982) in 1982. GRA is a useful method for solving problems where there are many criteria and complex and contradictory relationships between criteria. It is also a recommended method for solving complex relationships between variables. Depending on the degree of these associations, it considers the differences or similarities between two sequences in the form of a measure of varying correlation, which involves a comparison of data sets rather than the distance between two points (Lee & Lin, 2011; Tang & Young, 2013).

Gray relational Analysis method consists of seven steps (Karaatlı, Ömürbek, Budak, & Dağ, 2015; 2011):

Step 1: As a first step, the decision matrix is created. In the mxn-dimensional decision matrix, which consists of m number of alternatives and n number of criteria, the value of the ith alternative according to the j^{th} first criterion is expressed as x_{ij}.

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(n) \\ x_2(1) & x_2(2) & \cdots & x_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_m(1) & x_m(2) & \cdots & x_m(n) \end{bmatrix} \quad (1)$$

Step 2: In the next step, the data is normalized. With the normalization process, the decision matrix elements defined by different units are free from their units. Thus, it is possible to evaluate the criteria together. The normalization process is applied by using formula 2 when the criterion is a benefit criterion, and using formula 3 when it is a cost-oriented criterion.

$$x_i'(j) = \frac{x_i(j) - min\, x_i(j)}{max\, x_i(j) - min\, x_i(j)} \quad i = 1,2,\dots,m \quad j = 1,2,\dots,n \quad (2)$$

$$x_i'(j) = \frac{max\, x_i(j) - x_i(j)}{max\, x_i(j) - min\, x_i(j)} \quad i = 1,2,\dots,m \quad j = 1,2,\dots,n \quad (3)$$

Step 3: In this step, the difference of each value of the reference value determined by considering the maximization (benefit) or minimization (cost) criteria of the criteria is calculated, and the absolute value of these differences and the absolute value table of the distances to the reference values are obtained. Since the values of each criterion in the transformed decision matrix have values in the [0,1] value range, the reference value for the benefit criteria is determined as 1, while the reference value for the cost criteria is determined as zero.

$$x_i'(j) = 1 - \frac{|x_i(j) - x_0(j)|}{max\, x_i(j) - x_0(j)} \quad i = 1,2,\dots,m \quad j = 1,2,\dots,n \quad (4)$$

Step 4: In the matrix created in the previous step, the largest (Δmax) and smallest (Δmin) values for each criterion are determined.

Step 5: Gray relational coefficient values are calculated.

$$\varepsilon\,(x_0(j), x_i(j)) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(j) + \xi\Delta_{max}} \quad (5)$$

In the formula Δi(j); Δi represents the jth value in the difference data set. The coefficient ξ is used to eliminate the possibility of being the extreme value in the Δmax data set and is usually treated as 0.5 in the literature.

Step 6: Gray relational degrees (GRD) matrix is created by multiplying the gray relational coefficient values with the weights of the criteria.

$$\gamma(x_0, x_i) = \sum_{j=1}^{n} \varepsilon(x_0(j), x_i(j) * w_i(j)) \tag{6}$$

The $w_i(j)$ in the formula represents the weight for the *j*th data point.

Step 7: In the last step, GRD values are ordered from largest to smallest to obtain the ranking of the compared alternatives by GRA method. The alternative with the greatest value is defined as the best alternative in terms of the evaluated criteria.

The application consists of 18 quantitative indicators. Indicator codes and definitions are shown in Table 1.

Table 1. Indicator codes and definitions

Indicator Codes	Indicator Definitions	Indicator Codes	Indicator Definitions
C1	Forest area (million ha)	**C10**	Planted forest (million ha)
C2	Forest area (% of land area)	**C11**	… of which plantation forest (million ha)
C3	Growing stock (billion m3)	**C12**	Primary forest (million ha)
C4	Growing stock (m3/ha)	**C13**	Mangroves (million ha)
C5	Carbon stock in biomass (Gt)	**C14**	Forest in protected areas (million ha)
C6	Carbon stock in biomass (t/ha)	**C15**	Forest area with management plans (million ha)
C7	Total carbon stock (Gt)	**C16.1**	Protection of soil and water (million ha)
C8	Total carbon stock (t/ha)	**C16.2**	Conservation (million ha)
C9	Naturally regenerating forest (million ha)	**C16.3**	Social services (million ha)

3. Results

In the study, a total of 7 alternatives representing 6 regions and one for the whole world were evaluated in terms of forest quantity, quality and management using 18 indicators. Values for assessment indicators consist of 1990, 2000, 2010 and 2020 data in the Global Forest Resources Assessment 2020 Main Report. The GRA approach was used to evaluate the data from each of these years independently. The tables of the processing stages of the GRA technique for the year 2020 are presented in this part just to serve as an example of how the method works. To begin, using the GRA technique, a decision matrix consisting of indicator weights and indicator values for each alternative was built, as shown in Table 2. The equal weighting approach was used to determine the values of the weights.

After creating the decision matrices, the appropriate computations were performed using the procedures to get the normalized decision matrix shown in Table 3.

In the matrix created in the previous step, the largest (Δ_{max}) and smallest (Δ_{min}) values for each criterion were determined. The following matrix was created by calculating the absolute value of the difference ($\Delta_i(j)$) between the value of the alternative in the normalized matrix and the largest value (reference value) in the relevant column.

Table 2. GRA Decision matrix for 2020

wᵢ	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Regions	Max	Max	Max	Max	Max	Max	Max	Max	Max
World	4059	31.1	557	137.1	295	72.6	662	163.1	3737
Africa	637	21.3	76	120.0	51	79.4	81	127.1	625
Asia	623	20.0	63	100.4	38	60.3	85	136.1	487
Europe	1017	46.0	116	114.2	55	53.6	172	169.5	915
North and Central America	753	35.3	95	126.3	42	55.3	146	194.1	706
Oceania	185	21.8	19	101.8	14	74.9	33	178.5	180
South America	844	48.3	187	222.1	96	114.1	145	171.6	824
wᵢ	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
	C10	**C11**	**C12**	**C13**	**C14**	**C15**	**C16.1**	**C16.2**	**C16.3**
Regions	Max	Max	Max	Max	Max	Max	Max	Max	Max
World	293	131	825	14.7	629	1991	390	422	182
Africa	11	8	123	3.2	131	118	36	107	3
Asia	135	79	86	5.6	135	353	132	89	6
Europe	74	4	1	0.0	46	942	171	39	19
North and Central America	47	15	313	2.6	73	432	17	74	15
Oceania	5	4	3	1.3	28	12	1	31	0
South America	20	20	299	2.1	216	134	34	83	140

Table 3. GRA Normalized decision matrix

Wi	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Regions	Max	Max	Max	Max	Max	Max	Max	Max	Max
World	1	0.39222615	1	0.301561	1	0.31405	1	0.537313	1
Africa	0.116675	0.0459364	0.105948	0.161052	0.131673	0.426446	0.076312	1E-08	0.125105
Asia	0.113061	0.00000001	0.081784	1E-08	0.085409	0.110744	0.082671	0.134328	0.086309
Europe	0.214765	0.91872792	0.180297	0.113394	0.145907	1E-08	0.220986	0.632836	0.206635
North and Central America	0.146618	0.54063604	0.141264	0.212818	0.099644	0.028099	0.17965	1	0.147877
Oceania	1E-08	0.06360424	1E-08	0.011504	1E-08	0.352066	1E-08	0.767164	1E-08
South America	0.170108	1	0.312268	1	0.291815	1	0.17806	0.664179	0.181051
Reference Value	1	1	1	1	1	1	1	1	1
Wi	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
	C10	**C11**	**C12**	**C13**	**C14**	**C15**	**C16.1**	**C16.2**	**C16.3**
Regions	Max	Max	Max	Max	Max	Max	Max	Max	Max
World	1	1	1	1	1	1	1	1	1
Africa	0.022901	0.02913386	0.147634	0.220408	0.171381	0.053562	0.089506	0.194373	0.016484
Asia	0.45177	0.59055118	0.102709	0.377551	0.178037	0.172309	0.33642	0.148338	0.031319
Europe	0.240111	0.00000001	1E-08	1E-08	0.02995	0.469934	0.436728	0.02046	0.104396
North and Central America	0.146426	0.08818898	0.378331	0.173469	0.074875	0.212228	0.040638	0.109974	0.082418
Oceania	1E-08	0.00314961	0.001931	0.085714	1E-08	1E-08	1E-08	1E-08	1E-08
South America	0.053435	0.12677165	0.361333	0.144218	0.312812	0.061647	0.084362	0.132992	0.769231
Reference Value	1	1	1	1	1	1	1	1	1

Table 4. Distances and Absolute Value Matrix

Regions	C1	C2	C3	C4	C5	C6	C7	C8	C9
World	0.00000	0.60777	0.00000	0.69844	0.00000	0.68595	0.00000	0.46269	0.00000
Africa	0.88332	0.95406	0.89405	0.83895	0.86833	0.57355	0.92369	1.00000	0.87489
Asia	0.88694	1.00000	0.91822	1.00000	0.91459	0.88926	0.91733	0.86567	0.91369
Europe	0.78523	0.08127	0.81970	0.88661	0.85409	1.00000	0.77901	0.36716	0.79337
North and Central America	0.85338	0.45936	0.85874	0.78718	0.90036	0.97190	0.82035	0.00000	0.85212
Oceania	1.00000	0.93640	1.00000	0.98850	1.00000	0.64793	1.00000	0.23284	1.00000
South America	0.82989	0.00000	0.68773	0.00000	0.70819	0.00000	0.82194	0.33582	0.81895
Δmax	1	1	1	1	1	1	1	1	1
Δmin	0	0	0	0	0	0	0	0	0
ξ	0.5								
Regions	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16.1**	**C16.2**	**C16.3**
World	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Africa	0.97710	0.97087	0.85237	0.77959	0.82862	0.94644	0.91049	0.80563	0.98352
Asia	0.54823	0.40945	0.89729	0.62245	0.82196	0.82769	0.66358	0.85166	0.96868
Europe	0.75989	1.00000	1.00000	1.00000	0.97005	0.53007	0.56327	0.97954	0.89560
North and Central America	0.85357	0.91181	0.62167	0.82653	0.92512	0.78777	0.95936	0.89003	0.91758
Oceania	1.00000	0.99685	0.99807	0.91429	1.00000	1.00000	1.00000	1.00000	1.00000
South America	0.94656	0.87323	0.63867	0.85578	0.68719	0.93835	0.91564	0.86701	0.23077
Δmax	1	1	1	1	1	1	1	1	1
Δmin	0	0	0	0	0	0	0	0	0
ξ	0.5								

Then Gray Relational Coefficient values were calculated (ξ= 0.5), and Gray Relational Coefficient Matrix (K_j) values are shown in Table 5.

Tablo 5. Gray Relational Coefficient Matrix (K_j)

Regions	C1	C2	C3	C4	C5	C6	C7	C8	C9
World	1	0.45135566	1	0.417209	1	0.421603	1	0.51938	1
Africa	0.361448	0.34386391	0.358667	0.373427	0.36541	0.465743	0.3512	0.333333	0.363664
Asia	0.360506	0.33333334	0.352556	0.333333	0.353459	0.359905	0.352776	0.36612	0.353684
Europe	0.389034	0.86018237	0.378873	0.360593	0.369251	0.333333	0.390926	0.576592	0.386588
North and Central America	0.369445	0.52117864	0.367989	0.388446	0.357052	0.339697	0.378688	1	0.369789
Oceania	0.333333	0.34809348	0.333333	0.335909	0.333333	0.435565	0.333333	0.682281	0.333333
South America	0.37597	1	0.42097	1	0.413844	1	0.378232	0.598214	0.37909
Regions	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16.1**	**C16.2**	**C16.3**
World	1	1	1	1	1	1	1	1	1
Africa	0.338501	0.33993576	0.369722	0.39075	0.376331	0.345677	0.354486	0.382958	0.337037
Asia	0.476994	0.54978355	0.357835	0.445455	0.378225	0.376594	0.429708	0.369915	0.340441
Europe	0.39686	0.33333334	0.333333	0.333333	0.340125	0.485406	0.470247	0.337943	0.358268
North and Central America	0.369392	0.35415505	0.445764	0.376923	0.350846	0.388268	0.342615	0.359706	0.352713
Oceania	0.333333	0.33403472	0.333763	0.353535	0.333333	0.333333	0.333333	0.333333	0.333333
South America	0.345646	0.3641055	0.43911	0.368791	0.421163	0.34762	0.353198	0.365762	0.684211

Table 6 contains the Gray Relational Degrees calculation matrix and its values.

Table 6. Gray relational degrees and grades

Regions	C1	C2	C3	C4	C5	C6	C7	C8	C9	
World	0.056	0.025	0.056	0.023	0.056	0.023	0.056	0.029	0.056	
Africa	0.020	0.019	0.020	0.021	0.020	0.026	0.020	0.019	0.020	
Asia	0.020	0.019	0.020	0.019	0.020	0.020	0.020	0.020	0.020	
Europe	0.022	0.048	0.021	0.020	0.021	0.019	0.022	0.032	0.021	
North and Central America	0.021	0.029	0.020	0.022	0.020	0.019	0.021	0.056	0.021	
Oceania	0.019	0.019	0.019	0.019	0.019	0.024	0.019	0.038	0.019	
South America	0.021	0.056	0.023	0.056	0.023	0.056	0.021	0.033	0.021	
Regions	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16.1**	**C16.2**	**C16.3**	**Gray Relational Grades (GRG)**
World	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.878
Africa	0.019	0.019	0.021	0.022	0.021	0.019	0.020	0.021	0.019	0.364
Asia	0.026	0.031	0.020	0.025	0.021	0.021	0.024	0.021	0.019	0.383
Europe	0.022	0.019	0.019	0.019	0.019	0.027	0.026	0.019	0.020	0.413
North and Central America	0.021	0.020	0.025	0.021	0.019	0.022	0.019	0.020	0.020	0.413
Oceania	0.019	0.019	0.019	0.020	0.019	0.019	0.019	0.019	0.019	0.361
South America	0.019	0.020	0.024	0.020	0.023	0.019	0.020	0.020	0.038	0.514

The Gray Relational Grades (GRG) values in Table 7 were obtained by analyzing the values related to the other 10-year periods with the above-mentioned process steps.

Table 7. Gray Relational Grades (GRG) for 6 regions and the world in 10-year periods

Regions	1990	2000	2010	2020
World	0.823470	0.878920	0.878556	0.878211
Africa	0.355830	0.371020	0.367361	0.364011
Asia	0.364240	0.385420	0.384648	0.382784
Europe	0.365640	0.398750	0.405895	0.413052
North and Central America	0.387910	0.411040	0.412711	0.412961
Oceania	0.351240	0.367140	0.367082	0.360567
South America	0.495790	0.515280	0.514287	0.514295

In Figure 3, these values of the regions are shown graphically.

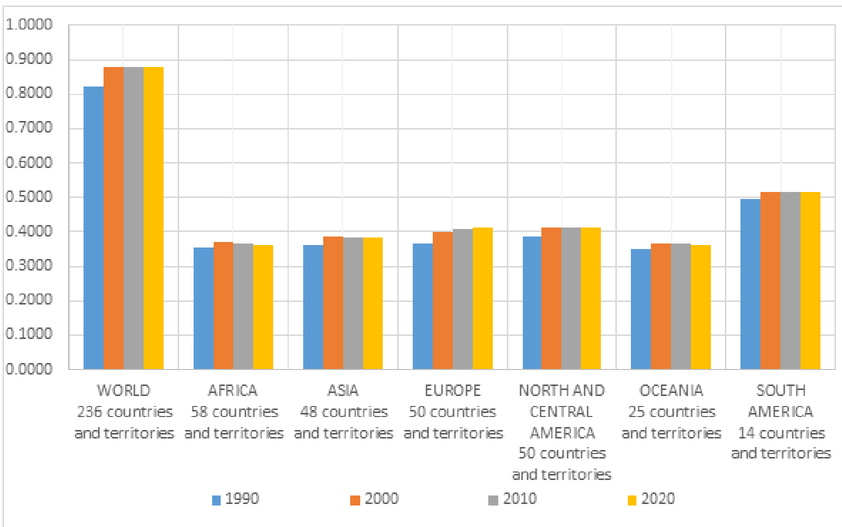

Figure 3. GRA scores of forest performance of the world in general and continents at 10-year intervals

It is necessary to mention some key statistics and inferences that should be emphasized globally and regionally in terms of the indicators included in the study in order to better understand the importance of forest management and the point reached in the field of forest in the last 30 years, both globally and regionally.

The tropics, followed by the boreal, temperate, and subtropical regions, has the greatest percentage of the world's forests (45 percent). Only five nations (the Russian Federation, Brazil, Canada, the United States of America, and China) account for more than half of the world's forests. From 7.8 million hectares per year in 1990–2000, net forest loss decreased to 5.2 million hectares per year in the decade 2000–2010 and to 4.7 million hectares per year in the ten years 2010–2020.

Africa, with an annual net loss of forest of 3.9 million ha, and South America, with a loss of 2.6 million ha, experienced the highest rates of net forest loss between 2010 and 2020. Since 1990, the pace of net forest loss in Africa has steadily grown. However, compared to the years 2000–2010, the rate has dropped dramatically in South America, and is now less than half of what it was. Following Oceania and Europe, Asia had the greatest net growth in forest area between 2010 and 2020. Despite this, Europe and Asia had fewer net gains in 2010–2020 than they did in 2000–2010. Oceania had net reductions in forest area between 1990 and 2000 and again between 2000 and 2010.

Deforestation has resulted in the loss of 420 million hectares of forest throughout the world since 1990, however this loss has slowed dramatically since then. During the years 2010–2015, deforestation totaled 12 million hectares; however, between 2015 and 2020, that number reduced to 10 million hectares.

A total of 7% (290 million hectares) of the world's forest land is planted, leaving 93% (3.75 billion ha) is made up of naturally renewing forest. Plantation forests have grown by more than 120 million hectares since 1990, whereas wild forests have shrunk at an ever decreasing pace. Increases in forested land have slowed considerably during the recent decade.

South America has the highest share of planted forest, comprising 99 percent of global planted forest area and 2% of total forest area. In Europe, plantation forest accounts for just 6% of planted national forest and 0.4 percent of forest areas. Worldwide, 44% of plantation forests are composed mostly of imported species. There are considerable geographical differences: for example, whereas plantation forests in North and Central America are dominated by indigenous species, those in South America are mainly dominated by foreign species.

Worldwide, protected areas cover an estimated 726 million hectares of forest. South America, with 31% of its forests in protected areas, has the greatest proportion of forests in protected areas among the six main geographical regions. Globally, the amount of forest in protected areas has expanded by 191 million hectares since 1990, however the yearly growth rate has decreased in the period 2010–2020. Although primary forest cover has decreased by 81 million hectares since 1990, the rate of decline has slowed to less than half in the period 2010–2020.

When the values of the regions in 1990 and 2020 are evaluated in terms of "C3 Growing stock (billion m3)" indicator, a total of 17 (billion m3) growing stock has increased in the world in a 30-year period. While there is an increase of 12 billion m3 in Europe, 5 in North and Central America and 11 billion m3 in Asia, there is a decrease in growing stock value of 12 billion m3 in Africa and 20 billion m3 in South America. Oceania's total volume of 19 billion m3 remained stable. For this metric, South America performs the worst, while Europe performs the best.

The indicator "C4 Growing stock (m3/ha)", in other words, "the average growing stock density" identifies trees of suitable quality for timber. Woodland trees that fall under this definition are generally larger, healthier trees, with long, straight trunks and low-growing branches. When the values of the regions between 1990 and 2020 are evaluated in terms of this indicator, an average of 5 (m3/ha) growing stock has increased in the world in a 30-year period. There are 9.3 (m3/ha) increase in Europe, 6.7 (m3/ha) increase in North and Central America, 20.3 (m3/ha) increase in Asia, 0.6 (m3/ha) increase in Oceania and 2 (m3/ha) increase in Africa, 9.3 (m3/ha) increase in South America ha). In terms of this indicator, Oceania region remained almost at the same level and showed the worst performance, while Asia showed the best performance with the increase it provided.

Biomass is the mass of biological organisms living in an ecosystem in a particular region or at a particular time. Carbon is stored in a variety of locations and forms across the globe. "Stock" refers to the quantity of carbon in a given system. Forests take up carbon through photosynthesis and this carbon is then allocated above and below ground, contributing to the global forest stock. There has been an increase of 3 (Gt) in the carbon stock in biomass (C5 Carbon stock in biomass) indicator values during the last 30 years. According to these indicator values, Europe has seen a rise of 10 (Gt) , Asia by 4 (Gt) , and North and Central America by 3 (Gt) . On the other hand, there is a decrease of 10 (Gt) in South America and 8 (Gt) in Africa. In the Oceania region, there was no change in this indicator value. Therefore, according to carbon stock in biomass (Gt) values, Europe shows the best performance, while South America and Africa show the worst performances.

According to the "C6 Carbon stock in biomass (t/ha)" indicator values, there is an increase of 2.3 (t/ha) worldwide. In this indicator value, there is an increase in the values of all other regions, except for the 0.5 (t/ha) decrease in the Oceania region over a 30-year period. There was an increase of 0.3 (t/ha) in Africa, 2.1 (t/ha) in Asia, 8.2 (t/ha) in Europe, 3.1 (t/ha) in North and Central America and 4.7 (t/ha) in South America. When the values are examined, Europe is clearly ahead of the other regions in this indicator with a significant value, and South America has a very good value.

According to the "C7 Total carbon stock (Gt)" indicator values, there is a decrease of 6 (Gt) worldwide in a 30-year period. According to these indicator values, there is an increase of 13 (Gt) in Europe and 3 (Gt) in North and Central America. On the other hand, there is a decrease of 17 (Gt) in South America, 13 (Gt) in Africa and 8 (Gt) in Asia. There is no change in the Oceania region. When this 30-year period is evaluated in terms of the relevant indicator, while Europe has the best indicator value, South America has the worst indicator value. According to the "C8 Total carbon stock (t/ha)" indicator values, there is an increase of 5.3 (t/ha) worldwide in the 30-year period. During this period, according to the relevant indicator, there is an increase of 9.8 (t/ha) in Europe, 4.4 (t/ha) in Asia, 3.5 (t/ha) in North and Central America, 5.5 (t/ha) in South America and 0.2 (t/ha) in Africa. There is a decrease of 1.7 (t/ha) in Oceania. While Europe achieved the best increase, South America and Asia also achieved very good increases.

According to the "C9 Naturally regenerating forest (million ha)" indicator values, there has been a decrease of 301 (million ha) worldwide in a 30-year period. During the same period, Europe was the only region showing an increase of 2 (million ha) among regions. There is a decrease of 109 (million ha) in Africa, 24 (million ha) in Asia, 26 (million ha) in North and Central America, 2 (million ha) in Oceania and 143 (million ha) in South America. Considering these values, Europe diverges positively, while Africa and South America perform quite poorly.

According to the "C10 Planted forest (million ha)" indicator values, there has been an increase of 123 (million ha) planted forests worldwide in a 30-year period. There is an increase of 2 (million ha) in Africa, 61 (million ha) in Asia, 20 (million ha) in Europe, 24 (million ha) in North and Central America, 2 (million ha) in Oceania and 13 (million ha) in South America. In this regard, Asia performed the best by a large margin, while Oceania and Africa performed the worst.

According to the "C11 … of which plantation forest (million ha)" indicator values, there has been an increase of 56 (million ha) worldwide in a 30-year period. There is an increase of 2 (million ha) in Africa, 29 (million ha) in Asia, 1 (million ha) in Europe, 8 (million ha) in North and Central America, 1 (million ha) in Oceania and 13 (million ha) in South America. While Asia is leading in this regard, it performs well in South America and North and Central America. According to the "C12 Primary forest (million ha)" indicator values, there has been an increase of 81 (million ha) worldwide in a 30-year period. There was no change in this period in Europe and Oceania. There is an increase of 20 (million ha) in Africa, 14 (million ha) in Asia and 4 (million ha) in North and Central America. In South America, a decrease of 43 (million ha) occurred. Africa shows the best performance in terms of these indicator values, while South America is the region with the worst value.

Mangrove forests, mangrove thickets, also called mangrove swamps, are fertile wetlands that occur in the tidal zones of the coast. Mangrove forests grow mostly in tropical and subtropical latitudes because mangrove trees cannot withstand freezing temperatures. There are about 80 different types of mangrove trees. All of these trees grow in areas with low-oxygen soils, where slow-moving waters allow fine sediments to build up. According to the "C13 Mangroves (million ha)" indicator values, it has decreased by 1.1 (million ha) worldwide in a 30-year period. While there has been no change in this period in Europe, an increase of 0.2 (million ha) in North and Central America and 0.1 (million ha) in South America. There is a decrease of 0.2 (million ha) in Africa, 0.7 (million ha) in Asia and 0.2 (million ha) in Oceania.

Over a 30-year period, the "C14 Forest in protected areas (million ha)" indicator values show a global increase of 191 (million ha). Over the last three decades, the relevant indicator value has risen for all areas. South America had the largest growth, with 66 million hectares, while Africa had the smallest increase, with 7 million hectares (million ha). North and Central America expanded by 31 (million hectares) and Oceania by 10 million (ha), whereas Asia grew by 50 (million ha) (million ha).

In 1990, there is no value for the indicator "C15 Forest area with management plans (million ha)". Therefore, for this indicator, data for the years 2000 and 2020 have been compared. All regions except Oceania had an increase in the relevant indicator value in this 20-year period. There has been an increase of 233 (million ha) "forest area with management plans" in the world. There was an increase of 39 (million ha) in Africa, 73 (million ha) in Asia, 8 (million ha) in Europe, 55 (million ha) in North and Central America and 69 (million ha) in South America. Increases are most pronounced in Asia, South and Central America, and North and Central America.

Preserving soil, water, and vegetation in regions at risk of degradation is the goal of local soil and water protection operations. These include efforts to reduce soil erosion, compaction, salinity, and water conservation, as well as efforts to preserve or increase soil fertility. According to the "C16.1 Protection of soil and water (million ha)" indicator values, there has been an increase of 94 (million ha) worldwide in a 30-year period. Europe outperforms the rest of the world on this statistic, with 80 (million hectares) in this period. There has been a 15 (million hectare) rise in Asia, a 1 (million hectare) increase in North and Central America, and a 3 (million hectare) increase in South America. The size of the protected area in Oceania has not changed over the last three decades.

The practice of conserving forests for the benefit of present and future generations is known as forest conservation. Forest conservation involves the maintenance of natural resources in a forest that are beneficial to both people and the ecosystem. According to the "C16.2 Conservation (million ha)" indicator values, there has been an increase of 75 (million ha) worldwide in a 30-year period. All areas have seen a rise in this metric. Asia (22 million ha) and North and Central America (21 million ha) are the areas that have had the greatest growth in the amount of conservation since 1990. 10 (million ha) in Africa, 11 (million ha) in Europe, 7 (million ha) in Oceania, and 5 (million ha) in South America have seen a rise.

According to the "C16.3 Social services (million ha)" indicator values, there has been an increase of 2 (million ha) worldwide in the 30-year period. Forest areas designated for social services are the most common kind of land in this category. In this 30-year period, while there has been an increase of 1 (million ha) in Africa, 2 (million ha) in Asia, 2 (million ha) in Europe, there has been no change in North and Central America and Oceania. In South America, there has been a decrease of 3 (million ha).

4. Discussion and Conclusion

The aims of the study are to contribute to the literature in terms of methodology by using the GRA method, one of the MCDM methods, and to increase awareness about forest quantity, quality and management. Another aim is to examine and compare the changes in the regions in terms of indicators determined over a 30-year period. The study brings a new perspective to the literature since the Gray relational analysis method has not been used to evaluate forest quantity, quality and management in a global context in terms of geographical regions before.

The 18 indicators in the Global Forest Resources Assessment 2020 Main Report used in the study have not assessed by MCDM or other analysis methods. Therefore, this is one of the aims and novelty of the study to the literature. Only a subset of 10 indicators has been frequently used to assess forest ecosystem management strategies, according to a review of the literature. This study was planned and carried out with these key aspects in mind. According to the literature, the most important indicators are "carbon stock," "tree species composition," and "forest degradation." In a research (Bowditch et al., 2020), most of these variables were designated fundamental indicators for evaluating forest and climate. Although Bowditch et al. (2020) indicates that social factors are an important part of the forest management in response to climate change, the opposite is true when it comes to scientific articles: ecological rather than economic factors are commonly discussed. In particular, findings of Santopuoli et al. (2021) show that “forest damage” is the most important indicator deciding the forest management rating. In this study, forest and carbon stock indicators were tried to evaluate the forest damage dimension, while the indicator related to forest social services was included in the analysis and the social dimension was taken into account. Therefore, it has been one of the rare studies evaluating the social aspect in this field.

In interregional comparisons, the South America region has the best values. Oceania, on the other hand, is ranked at the bottom of the list. The main reason for this result is that the forest area (million ha) of the Oceania region is quite less compared to other regions. On the other hand, the ratio of forest area to terrestrial area (21.8%) of the Oceania region is approximately equal to that of Africa and Asia. While the ratio of forest area in South America (48.3%) and Europe (46%) to the total terrestrial area is approximately twice that of Asia, Africa and Oceania, they are approximately 1.5 times that of North and Central America. While the GRA scores for all regions and the world have increased significantly from 1990 to 2000, the performance values for the years 2000, 2010 and 2020 are very close to each other. In all rankings, South America is in the first place, while Oceania is in the last place. Meanwhile, in the 2020 rankings, Europe moved up from third to second place, just a few points ahead of North and Central America.

It's important to note that underutilized forest resources are more sensitive to natural catastrophes and may release more carbon than harvested forest resources in the case of degradation (Jandl, Spathelf, Bolte, & Prescott, 2019). Therefore, the amount of managed forest should increase at a faster pace. When the indicators of the study on this subject are evaluated, the majority of forest areas in Europe have a management action plan; by contrast, fewer than 25% of forests in Africa and less than 20% in South America have implementation strategies. The amount of forest managed under plans is expanding in all areas worldwide, it has expanded by 233 million hectares (ha) since 2000, and reached to almost 2.05 billion hectares in 2020. In 2015, insects, diseases, and severe weather damaged approximately 40 million hectares of forest, mostly in temperate and boreal areas.

Rotation time of forest harvesting operations may increase both the growing stock and the quality of wood products (Jandl et al., 2018; Jandl et al., 2019; Köhl, Ehrhart, Knauf, & Neupane, 2020). An adaptive management plan, which includes increased wood collection, might allow long-term carbon storage in forest products, in addition to the economic benefits already described (Colombo et al., 2012; Jasinevičius, Lindner, Verkerk, & Aleinikovas, 2017; Paletto, De Meo, Grilli, & Nikodinoska, 2017). As a result of these research, it is safe to say that nations and regions with a long-term strategy for managing forest and carbon stock will have a positive impact on their own economy and the environment (Santopuoli et al., 2021). When the analysis in the study is taken into account, Europe under the leadership of Russia and EU; Asia led by China; and North America, led by Canada and the USA, are important actors.

All regions and the majority of subregions are dominated by public ownership. Oceania, North and Central America, and South America have the largest percentage of private forests among the continents. Since 1990, the percentage of publicly held forests has dropped globally, while the amount of privately owned forest has expanded.

A net loss in forest area has reduced the world's total growing supply of trees from 560 billion m^3 in 1990 to 557 billion m3 in 2020. But worldwide and regional growing stock per unit area is rising; it has gone from 132 m^3 per ha per year in 1990 to 137 m^3 per ha in 2020. Most trees are grown per square meter in South and Central America's tropical forests, as well as West and Central Africa's rainforests. About 606 gigatonnes of live biomass (both above and below ground) and 59 gigatonnes of dead wood are available in the world's forests. Biomass as a whole has fallen significantly since 1990, while biomass as a percentage of land area has risen. In addition, carbon storage in forests declined from 668 gigatonnes in 1990 to 662 gigatonnes in 2020; carbon density grew slightly over the same time, from 159 to 163 tonnes per hectare. Around the globe, 186 million hectares of forest are set aside for social activities such as leisure, ecotourism, training, and the protection of spiritual and cultural places. Since 2010, the area allocated for this forest use has expanded by 186 000 hectares each year.

There should be no negative consequences of forest use and management for both the public's health and the environment. Environment-related problems must no longer be ignored or avoided. Policymakers must come up with a common strategy for more effective protection and long-term sustainability of forest resources in order to achieve these goals. Increasing the pace of research and development, education, and public awareness, as well as increasing incentives and investments in the infrastructure of standard data collection systems, will all contribute to the achievement of the Sustainable Development Goals. Global awareness, cooperation, policies, and strategies will bring us closer to a sustainable world in which forest resources are protected and global climate problems can be brought under control as a result of our collective efforts.

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Düzce yöresi ballarında polen analizi

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Özet

2019 ve 2020 yılları arasında Düzce ili ve ilçelerinden (Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı, Yığılca) 34 bal örneği toplanmış ve bunların polen analizi yapılmıştır. Yapılan analiz sonucunda Düzce yöresi ballarında 20'si familya, 69'u cins ve 20'si tür düzeyinde toplam 109 taksonun poleni teşhis edilmiştir. Bu polenler çoğunlukla Apiaceae, Asteraceae, Boraginaceae, Brassicaceae, Ericaceae, Fabaceae, Fagaceae, Plantaginaceae, Poaceae ve Rosaceae familyalarına aittir. Balda polenlerine en yüksek oranda rastlanan takson yörenin doğal bitkilerinden olan *Castanea sativa* Miller (kestane) türüdür. İncelenen 34 bal örneğinden 12 tanesi monofloral (tek çiçek kaynaklı) bal olarak belirlenmiştir. Monofloral balların 8 tanesi *Castanea sativa*, 3 tanesi *Rhododendron ponticum* L. (ormangülü) ve 1 tanesi Ailanthus altissima (Miller) Swingle (kokarağaç) balı olarak tanımlanmıştır. Geriye kalan 22 adet bal örneği ise polifloral (çok çiçek kaynaklı) bal olarak tanımlanmıştır. Yapılan analizler sonucunda ballardaki takson çeşitliliği en yüksek düzeyde olan familyanın 17 örnekle Asteraceae, ikinci familyanın 11 örnekle Rosaceae ve üçüncü familyanın 9 örnekle Fabaceae olduğu belirlenmiştir.

Anahtar sözcükler: Polen analizi, Bal, Melissopalinoloji, Düzce.

Abstract

In this study, 34 honey samples were collected from Düzce province and its districts (Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı, Yığılca) between 2019-2020 and pollen analysis was carried out in the samples. A total as 109 taxa including 20 in families, 69 in genera and 20 in species level, were identified in Düzce honey. Most of these pollen belong to the families of Apiaceae, Asteraceae, Boraginaceae, Brassicaceae, Ericaceae, Fabaceae, Fagaceae, Plantaginaceae, Poaceae and Rosaceae. The taxon with the highest rate of pollen in honey is *Castanea sativa* Miller (chesnut) species, which is one of the natural plants of the region. 12 of 34 honey samples examined were determined as monofloral (single flower origin) honey. Eight of the monofloral honeys were defined as *Castanea sativa*, 3 as *Rhododendron ponticum* L. and 1 as *Ailanthus altissima* (Miller) Swingle honey. The remaining 22 honey samples were determined as polyfloral (multi-floral origin) honey. As a result of the analysis, it was determined that the family with the highest taxa diversity in honey was Asteraceae with 17 samples, Rosaceae with 11 samples from the second family and Fabaceae with 9 samples from the third family.

Keywords: Pollen analysis, Honey, Melissopalynology, Düzce.

Giriş

Türk Gıda Kodeksi Bal Tebliği'ne göre bal; bitki nektarlarının, bitkilerin canlı kısımlarının salgılarının veya bitkilerin canlı kısımları üzerinde yaşayan bitki emici böceklerin salgılarının bal arısı (*Apis mellifera* L.) tarafından toplandıktan sonra kendine özgü maddelerle birleştirerek değişikliğe uğrattığı, su içeriğini düşürdüğü ve petekte depolayarak olgunlaştırdığı doğal bir ürün olarak tanımlanmaktadır (Anonim, 2020).

Bal, geçmişten günümüze değin insanlar için değerli bir besin maddesi olarak önemini korumaktadır. Ancak balın kalitesi, üretildiği bölgenin coğrafik yapısı ve elde edildiği bitkiye bağlı olarak değişiklik göstermektedir. Balın kalitesini ortaya koyan en önemli kriter kimyasal ve fiziksel özelliklerinin yanı sıra sahip olduğu polen içeriğidir (Terzi, 2009).

Balların polen içeriğini üretimin yapıldığı bölgeye ait floristik çeşitlilik önemli ölçüde belirler (Erdoğan, 2007). Çeşitli iklimsel özelliklerin hüküm sürdüğü ve yaklaşık 12.000 bitki türüne ev sahipliği yapan ülkemiz arıcılık açısından önemli bir potansiyele sahiptir. Ülkemizin sahip olduğu zengin bitki çeşitliliğine yönelik çok sayıda çalışma olmasına rağmen bal üretimine hangi bitkilerin katkı sağladığı konusunda detaylı çalışmalara gereksinim duyulmaktadır. Bu nedenle bitki çeşitliliğinin bal üretimine katkısının belirlenmesinde yardımcı olacak en önemli yöntemlerden biri balda polen analizidir. Ülkemizde üretilen balların palinolojik açıdan incelenmesine yönelik çalışmaların son yıllarda artması, bala kaynak oluşturan nektarlı bitkilerin belirlenmesi ve ürün kalitesinin arttırılmasını hedeflemektedir (Kemancı, 1999). Yapılan polen analizleri sonucunda balın bitkisel orijinin belirlenmesinin yanı sıra kötü tat, acılık, hızlı kristalleşme ve toksik etki gösteren balların polen tanımlaması yapılabilmektedir. Bu tür çalışmalar sonucunda balların niteliklerinin ortaya konulmasıyla değerinde de artış sağlanacaktır.

Balda polen analizi ilk kez 1845'te Pfister tarafından yapılmıştır ve devamında tüm dünyada polen analizi çalışmaları hız kazanmıştır. Türkiye ballarında ise polen analizi ilk olarak Quistani tarafından 1976 yılında gerçekleştirilmiş (Sorkun vd., 1989), ardından Aytuğ, 1967; Sorkun, 1982; Sorkun ve İnceoğlu, 1984a; Sorkun vd., 1989; Dalgıç, 1994; Sorkun ve Doğan, 1995; Başoğlu vd., 1996; Kemancı, 1999; Bağçı ve Tunç, 2006; Erdoğan vd., 2006; Erdoğan, 2007; Erdoğan vd., 2009; Taşkın ve İnce, 2009; Kelez, 2009; Terzi, 2009; Mısır, 2011; Bakoğlu vd., 2014; Güzel, 2014; Kambur vd., 2015; Özler, 2015; Yalçın, 2015; Fişne, 2016; Bayramlı vd., 2016; Şık vd., 2017; Atalay vd., 2018; Gürbüz vd., 2019; Uzunca, 2019; Yıldırım, 2020 yıllarında Türkiye'nin farklı yörelerinde çalışmalarını gerçekleştirmiştir.

Çalışma alanımız olan Düzce bal arısı ırkı olarak önemli bir ekotipe ev sahipliği yapmaktadır. Kekeçoğlu (2007), yapmış olduğu çalışmada Düzce'den temin edilen bal arısı örneklerinin diğer bal arısı örneklerinden morfolojik olarak farklılık gösterdiğini tespit etmiştir. Kekeçoğlu (2009), Batı Karadeniz'de bal arısı biyoçeşitliliği üzerine yapmış olduğu çalışmada genetik ve morfolojik verilerden yararlanarak Düzce ili için *Apis mellifera* L. *anatoliaca* ekotipi olan Yığılca ekotipini tanımlamıştır.

Bu çalışma kapsamında, özel bir bal arısı ekotipine (Yığılca ekotipi) sahip olan Düzce ili ve ilçelerine ait bal örneklerinde bitki çeşitliliğinin belirlenmesine yönelik melissopalinolojik analizler yapılmıştır. Yapılmış olan melissopalinolojik çalışmalar ile bölgede arılar için nektar ve polen potansiyeline sahip bitkilerin belirlenmesi ve Düzce ili nektarlı bitkiler listesinin oluşturulması amaçlanmıştır.

Çalışma alanı olarak seçilen bölgede daha önce 2 melissopalinolojik çalışma gerçekleştirilmiş ancak bu çalışmalar lokal ölçektedir. Düzce ili Yığılca ilçesinin bal örneklerini içeren çalışmalar Kambur vd. (2015) ve Yıldırım (2020) tarafından yapılmıştır. Yapılan bu çalışma Düzce il ve tüm ilçelerini (Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı, Yığılca) kapsaması yönünden farklılık ve çeşitlilik sunmaktadır.

Materyal ve Yöntem

34 adet bal örneği Düzce ili Merkez (4) ve 7 ilçesindeki (Akçakoca (4), Cumayeri (4), Çilimli (3), Gölyaka (5), Gümüşova (2), Kaynaşlı (5), Yığılca (7) arıcılardan temin edilmiştir. Örneklerin her biri bir arılığı temsil etmektedir. Bal toplama işlemi 2019 – 2020 yılları arasında bal sağım zamanının sonunda gerçekleştirilmiştir. Bal örnekleri alınırken arılıkların birbirine olan uzaklıklarına, sabit tutulan arılıklardan olmasına ve alınan örneklerin ağırlıklarının en az 250 gram olmasına dikkat edilmiştir. Süzme bal olarak alınan örnekler steril kavanozlara konularak oda sıcaklığında, nemsiz ve karanlık bir dolapta muhafaza edilmiştir. Kavanozlar üzerine balın alındığı yörenin adı, alınış tarihi ve üretici isimleri yazılarak, incelenmek üzere Düzce Üniversitesi Fen Edebiyat Fakültesi Biyoloji Bölümü Botanik Araştırma Laboratuvarı'na getirilmiştir.

Polen Preparatlarının Hazırlanması

Bal örneklerinin botanik orijinini belirlenmek için sekiz Avrupa ülkesinin arıcılık enstitülerinde çalışan uzmanlarca incelenip uluslararası bir metot olarak kabul edilen preparat hazırlama yöntemi kullanılmıştır (Maurizio 1951; Louveaux vd. 1970; Lieux 1972). Preparatların hazırlanmasında kullanılan montaj materyali Wodehouse yöntemine göre hazırlanmıştır (Aytuğ 1967).

Bunun için kristalleşmiş ve soğuktan katılaşmış olan ballar 40-45ºC'lik sıcak su banyosunda bir süre erimesi için bekletilmiştir. Daha sonra cam baget ile karıştırılan ballar homojen hale getirilmiş ve içerisinden 10 gram tartılarak deney tüplerine aktarılmıştır. Deney tüpleri üzerinde 20 ml distile su ilave edildikten sonra 40-45ºC'de 10-15 dakika sıcak su banyosunda bekletilmiştir. Sıcak su banyosundan çıkartılıp vortekslenen deney tüpleri 3500-4000 rpm'de 45 dakika santrifüj edilmiştir. Cihazdan çıkarılan tüpler içerisindeki sıvı kısım çökeltiye zarar vermeden dökülmüş ve tüpler kurumaları için ters çevrilip bekletilmiştir. Daha sonra steril iğne ucuna alınan (1-2 mm^3) safraninli gliserin jelatin dipteki çökeltiye bulaştırılmış ve lam üzerine aktarılmıştır. Isıtıcı tabla üzerine yerleştirilen montaj materyali eridikten sonra üzerine lamel kapatılmıştır. Etiketlenip ters çevrilen preparat 12 saat bekletildikten sonra incelemeye hazır hale gelmiştir.

Hazırlanan Polen Preparatının İncelenmesi

Hazırlanan polen preparatının teşhisi Nikon H550S marka mikroskoba bağlı Nikon DS-U3 marka görüntüleme sistemi ile gerçekleştirilmiştir. İncelemelerde 22x22'lik lamel alanı taranmış ve polen teşhisi yapılmıştır. Polenlerin teşhisinde, Düzce Üniversitesi Fen Edebiyat Fakültesi Biyoloji Bölümü Botanik Araştırma Laboratuvarı'nda yer alan ve 2018-2020 yılları arasında Düzce'nin farklı lokalitelerinden toplanılmış referans bitki koleksiyonundan hazırlanmış polen preparatları, Türkiye'nin nektarlı bitkileri, polenleri ve balları kitabı (Sorkun, 2008), The global pollen project, Paldat internet sayfaları ve daha önce yapılmış olan balda polen analizi çalışmalarından yararlanılmıştır. Alanda 200 adet polen sayılmıştır (Louveaux vd. 1970; Sawyer 1981). Taksonların polen ortalamaları ve yüzdeleri belirlenip, polen spektrumlarına göre 4 ana gruba (dominant, ≥ %45; sekonder, %44-%16; minör, %15-%3; eser ≤ %3) ayrılmıştır (Barbattini vd. 1991; Warakomska ve Jaroszynska 1992).

Bulgular

Çalışma kapsamında Düzce yöresinden 34 bal örneği temin edilmiş ve alınan bal örnekleri üzerinde yapılan polen analizleri sonucunda 20'si familya, 69'u cins ve 20'si tür düzeyinde toplam 109 taksonun poleni teşhis edilmiştir. Yapılan polen analizleri sonucunda yöre ballarında rastlanan takson sayısı 17-44 arasında değişmektedir (Tablo 1). Çalışma sonucunda incelenen 34 bal örneğinin 12 tanesinin monofloral (tek çiçek kaynaklı), 22 tanesinin polifloral (çok çiçek kaynaklı) bal olduğu tespit edilmiştir. Monofloral ballardan 8'i *Castanea sativa* Miller (kestane) (Fagaceae), 3'ü *Rhododendron ponticum* L. (ormangülü) (Ericaceae) ve 1 tanesi de *Ailanthus altissima* (kokar ağaç) (Simaroubaceae) balı olarak adlandırılmıştır. Polifloral ballardan Yığılca 3 numaralı bal örneği Fagaceae familyasından *Castanea sativa* (kestane) ve *Qercus* sp. (meşe) polenlerini farklı oranlarda barındırdığı için Fagaceae familyası balı, Akçakoca 4 ve Merkez 3 numaralı bal örnekleri ise *Castanea sativa* (Fagaceae) ve *Tilia* sp. (Tiliaceae) taksonlarını farklı oranlarda barındırdığı için Ihlamur/Kestane balı olarak adlandırılmıştır. Geriye kalan polifloral ballar karışık çiçek balı olarak isimlendirilmiştir.

Akçakoca 1 numaralı bal örneğinde 18 familyaya ait 22 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Castanea sativa* (Fagaceae) poleni sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Akçakoca 2 numaralı bal örneğinde 23 familyaya ait 30 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Castanea sativa* (Fagaceae) poleni sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Akçakoca 3 numaralı bal örneğinde 19 familyaya ait 25 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Castanea sativa* (Fagaceae) poleni sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Akçakoca 4 numaralı bal örneğinde 17 familyaya ait 22 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Cumayeri 1 numaralı bal örneğinde 21 familyaya ait 31 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Cumayeri 2 numaralı bal örneğinde 21 familyaya ait 29 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Cumayeri 3 numaralı bal örneğinde 21 familyaya ait 29 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Cumayeri 4 numaralı bal örneğinde 18 familyaya ait 24 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Çilimli 1 numaralı bal örneğinde 25 familyaya ait 33 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Çilimli 2 numaralı bal örneğinde 23 familyaya ait 31 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Castanea sativa* (Fagaceae) poleni sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Çilimli 3 numaralı bal örneğinde 20 familyaya ait 23 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Castanea sativa* (Fagaceae) ve *Rubus* sp. (Rosaceae) polenleri sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Gölyaka 1 numaralı bal örneğinde 23 familyaya ait 26 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. Sekonder düzeyde tespit edilen polenler Apiaceae, *Rhododendron ponticum* (Ericaceae) ve *Castanea sativa* (Fagaceae) taksonlarına aittir. Diğer taksonların polenleri minör ve eser düzeyde gözlenmiştir.

Gölyaka 2 numaralı bal örneğinde 22 familyaya ait 31 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Taraxacum* sp. (Asteraceae) ve Rosaceae taksonlarına ait polenler sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Gölyaka 3 numaralı bal örneğinde 28 familyaya ait 40 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Gölyaka 4 numaralı bal örneğinde 21 familyaya ait 25 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant düzeyde polen tespit edilmemiştir. Sekonder düzeyde tespit edilen polenler *Taraxacum* sp. (Asteraceae) ve *Rhododendron ponticum* (Ericaceae) taksonlarına aittir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Gölyaka 5 numaralı bal örneğinde 15 familyaya ait 19 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Gümüşova 1 numaralı bal örneğinde 20 familyaya ait 29 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Gümüşova 2 numaralı bal örneğinde 16 familyaya ait 19 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant polene rastlanmamıştır. *Castanea sativa* (Fagaceae) ve Fabaceae familyası polenleri sekonder düzeyde gözlenmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Kaynaşlı 1 numaralı bal örneğinde 24 familyaya ait 35 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Kaynaşlı 2 numaralı bal örneğinde 24 familyaya ait 32 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant ve sekonder düzeyde polen tespit edilmemiştir. Tespit edilen taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Kaynaşlı 3 numaralı bal örneğinde 12 familyaya ait 20 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder ve minör düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler eser düzeyde gözlenmiştir.

Kaynaşlı 4 numaralı bal örneğinde 19 familyaya ait 25 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder ve minör düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler eser düzeyde gözlenmiştir.

Kaynaşlı 5 numaralı bal örneğinde 25 familyaya ait 35 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder ve minör düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler eser düzeyde gözlenmiştir.

Merkez 1 numaralı bal örneğinde 15 familyaya ait 17 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Merkez 2 numaralı bal örneğinde 20 familyaya ait 33 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant oranda polene rastlanmamıştır. Sekonder düzeyde tespit edilen polen *Calystegia* sp. (Convolvulaceae) taksonuna aittir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Merkez 3 numaralı bal örneğinde 20 familyaya ait 26 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Merkez 4 numaralı bal örneğinde 14 familyaya ait 20 taksonun poleni teşhis edilmiştir. Bal örneğinde *Ailanthus altissima* (Simaroubaceae) poleni dominant oranda gözlenirken *Helianthus annuus* (Asteraceae) poleni sekonder düzeyde tespit edilmiştir. Minör düzeyde polene rastlanmamıştır. Diğer taksonlara ait polenler eser düzeyde gözlenmiştir.

Yığılca 1 numaralı bal örneğinde 29 familyaya ait 44 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Yığılca 2 numaralı bal örneğinde 19 familyaya ait 26 taksonun poleni teşhis edilmiştir. Bal örneğinde *Rhododendron ponticum* (Ericaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Yığılca 3 numaralı bal örneğinde 21 familyaya ait 36 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant, *Quercus* sp. (Fagaceae) polenleri sekonder düzeyde tespit edilmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Yığılca 4 numaralı bal örneğinde 20 familyaya ait 27 taksonun poleni teşhis edilmiştir. Bal örneğinde dominant düzeyde polen tespit edilmemiştir. *Erica* sp. (Ericaceae) ve *Fagus orientalis* polenleri (Fagaceae) sekonder düzeyde tespit edilmiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Yığılca 5 numaralı bal örneğinde 18 familyaya ait 26 taksonun poleni teşhis edilmiştir. Bal örneğinde *Castanea sativa* (Fagaceae) poleni dominant düzeyde tespit edilmiştir. Sekonder ve minör düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler eser düzeyde gözlenmiştir.

Yığılca 6 numaralı bal örneğinde 15 familyaya ait 24 taksonun poleni teşhis edilmiştir. Bal örneğinde *Rhododendron ponticum* (Ericaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Yığılca 7 numaralı bal örneğinde 18 familyaya ait 29 taksonun poleni teşhis edilmiştir. Bal örneğinde *Rhododendron ponticum* (Ericaceae) poleni dominant oranda gözlenirken sekonder düzeyde polen tespit edilmemiştir. Diğer taksonlara ait polenler minör ve eser düzeyde gözlenmiştir.

Çalışma kapsamından incelenen 34 bal örneğinin polen spektrumları yüzdeleri ile birlikte Tablo 1'de, teşhis edilen polenlerin mikrofotoğrafları Tablo 2'de verilmiştir.

Tablo 1. Düzce yöresi balları polen spektrumları ve takson sayıları.

Bal Örnekleri	Dominant polenler ≥ %45	Sekonder polenler %44-%16	Minör polenler %15-%3	Eser polenler ≤ %3	Takson Sayısı
A1		*Castanea sativa* Mill. (%43,69)	Apiaceae (%14,32), *Helianthus annuus* L. (%14,07), *Rumex* sp.(%4,36), *Tilia* sp. (%3,64), *Trifolium* sp. (%3,4)	Amarathaceae (Chenopodiaceae) (%0,24), *Anthemis* sp. (%0,72), *Cichorium intybus* L. (%2,66), *Cistus* sp. (%2,18), *Echium vulgare* L. (%0,24), Ericaceae (%1,21), *Geranium* sp. (%1,21), *Ilex aquifolium* L. (%0,24), *Juglans regia* L. (%0,97), *Laurus nobilis* L. (%0,97), *Ligustrum vulgare* L. (%0,48), *Plantago* sp. (%1,21), Poaceae (%2,66), *Potentilla* sp. (%0,97), *Rhododendron ponticum* L. (%0,24) ve *Sanguisorba* sp. (%0,24)	22
A2		*Castanea sativa* (%35,3)	Apiaceae(%8,06), Brassicaceae (%6,38), *Echium vulgare* (%12), *Helianthus annuus* (%11,9), *Rubus* sp. (%3,02), *Rumex* sp. (%3,7), *Salix* sp. (%5,38)	*Alnus* sp. (%0,34), Amaranthaceae (Chenopodiaceae) (%0,17), *Centaurea* sp. (%1,18), *Cichorium intybus* (%2,67), *Cistus* sp. (%1,68), Fabaceae (%1,51), *Geranium* sp. (%1,18), *Ilex aquifolium* (%0,17), *Juglans regia* (%0,17), *Laurus nobilis* (%0,67), *Ligustrum vulgare* (%0,34), *Plantago* sp. (%1,68), Poaceae (%1,51), *Pyracantha coccinea* M. Roem. (%2,18), *Quercus* sp. (%0,34), Ranunculaceae (%0,84), Rhamnaceae (%0,17), *Rhododendron ponticum* (%2,18), *Rosa canina* L. (%1,85), *Sanguisorba* sp. (%0,17), *Tilia* sp. (%2,25) ve *Zinnia* sp. (%0,67)	30
A3		*Castanea sativa* (%44,58)	Apiaceae (%12,65), *Helianthus annuus* (%9,04), *Sambucus ebulus* L. (%5,12), *Rubus* sp. (%5,42)	Amaranthaceae (Chenopodiaceae) (%0,6), *Anthemis* sp. (%1,2), *Cistus* sp. (%0,6), Ericaceae (%0,9), Fabaceae (%2,11), *Fagus orientalis* Lipsky (%2,71), *Geranium* sp. (%2,11), *Juglans regia* (%0,6), *Laurus nobilis* (%0,6), *Ligustrum vulgare* (%0,6), *Pinus* sp. (%0,6), *Plantago* sp. (%1,2), Poaceae (%1,5), *Potentilla* sp. (%0,6), *Quercus* sp. (%1,2), Ranunculaceae (%0,6), *Rhododendron ponticum* (%0,3), *Rumex* sp. (%2,41), *Taraxacum* sp. (%1,81) ve *Tilia* sp. (%2,41)	25
A4	*Castanea sativa* (%47,8)		Apiaceae (%7,17), *Plantago* sp. (%8,23), Ranunculaceae (%4,91), *Rosa canina* (%5,84), *Rubus* sp. (%5,18), *Tilia* sp. (%6,5)	*Allium cepa* L.(%0,13), *Anthemis* sp. (%0,4), *Calystegia* sp. (%0,4), *Echium vulgare* L. (%2), *Fagus orientalis* (%0,93), *Juglans regia* (%0,4), Lamiaceae (%0,13), *Laurus nobilis* (%0,26), *Ligustrum vulgare* (%0,53), *Medicago* sp. (%2,39), Poaceae sp. (%1,46), *Potentilla* sp. (%1,33), *Rumex* sp. (%0,8), *Taraxacum* sp. (%1,46) ve *Trifolium* sp. (%1,72)	22
C1	*Castanea sativa* (%74,8)		Poaceae (%5,16)	*Allium cepa* (%0,08), Apiaceae (%1,34), *Arctium minus* (Hill) Bernh. (%0,17), Brassicaceae (%2,76), *Cichorium intybus*	31

			(%0,71), *Cistus* sp. (%0,35), *Cota tinctoria* var. *pallida* (DC) Özbek & Vural (%0,35), Ericaceae (%0,35), *Fagus orientalis* (%0,44), *Geranium* sp. (%0,08), *Hedysarum* sp. (%0,89), *Helianthus annuus* (%0,08), Lamiaceae (%0,17), *Laurus nobilis* (%0,17), *Ligustrum vulgare* (%0,08), *Onobrychis* sp. (%0,62), *Plantago* sp. (%1,6), *Potentilla* sp. (%0,27), *Quercus* sp. (%1,25), *Ranunculus* sp. (%0,08), *Rhododendron ponticum* (%0,27), *Rosa canina* (%1,42), *Rubus* sp. (%2,13), *Rumex* sp. (%0,17), *Salix* sp. (%1,06), *Sambucus ebulus* (%0,53), *Scabiosa* sp. (%0,27), *Tilia* sp. (%0,35) ve *Trifolium* sp. (%1,78)	
C2	*Castanea sativa* (%81,26)	Poaceae (%4,74)	*Acer* sp. (%0,34), *Agrimonia* sp. (%1,35), Apiaceae (%1,24), *Artemisia* sp. (%0,11), Brassicaceae (%1,69), *Campanula* sp. (%0,11), *Cistus* sp. (%0,45), *Cota tinctoria* var. *pallida* (%0,11), *Cupressus* sp. (%0,11), *Echium vulgare* (%0,34), Ericaceae (%0,56), *Geranium* sp. (%0,11), *Helianthus annuus* (%0,22), *Medicago* sp. (%0,45), *Pinus* sp. (%0,11), *Plantago* sp. (%1,8), *Potentilla* sp. (%0,45), *Quercus* sp. (%0,11), *Rhododendron ponticum* (%0,34), *Rorippa* sp. (%0,79), *Rumex* sp. (%0,22), *Salix* sp. (%1,01), *Scabiosa* sp. (%0,11), *Taraxacum* sp. (%0,45), *Tilia* sp. (%0,22) ve *Trifolium* sp. (%1,12)	29
C3	*Castanea sativa* (%74,84)	Brassicaceae (%3,25), Poaceae (%5,2)	*Acer* sp. (%0,1), Apiaceae (%0,98), Betulaceae (%0,1), *Carduus* sp. (%0,1), *Cistus* sp. (%0,98), *Clematis* sp. (%0,32), *Cota tinctoria* var. *pallida* (%0,1), *Echium vulgare* (%0,54), Ericaceae (%0,87), *Helianthus annuus* (%0,43), Lamiaceae (%0,1), *Ligustrum vulgare* (%0,32), *Plantago* sp. (%1,3), *Potentilla* sp. (%0,76), *Quercus* sp. (%0,98), Ranunculaceae (%0,1), Rhamnaceae (%0,1), *Rhododendron ponticum* (%0,21), *Rorippa* sp. (%1,08), Rosaceae (%0,54), *Rumex* sp. (%0,32), *Salix* sp. (%1,19), *Sambucus ebulus* (%2,17), *Taraxacum* sp. (%0,76), *Tilia* sp. (%0,43) ve *Trifolium* sp. (%1,73)	29
C4	Castanea sativa (%64,55)	Apiaceae (%5,6), *Echium vulgare* (%3,41), *Salix* sp. (%3,89), *Sambucus ebulus* (%5,85)	*Allium cepa* (%0,12), Asteraceae (%0,49), Betulaceae (%0,24), Brassicaceae (%1,83), *Cichorium intybus* (%0,24), *Cistus* sp. (%0,6), *Crateagus* sp. (%0,6), *Cornus* sp. (%0,97), *Laurus nobilis* (%0,24), *Medicago* sp. (%1,22), *Plantago* sp. (%2,07), Poaceae (%1,22), *Potentilla* sp. (%0,37), *Quercus* sp. (%1,09),	24

				Ranunculaceae (%0,24), *Rorippa* sp. (%0,49), *Rosa canina* (%1,09), *Tilia* sp. (%0,73) ve *Trifolium* sp. (%2,8)	
Ç1	*Castanea sativa* (%55,93)		Apiaceae (%3,24), *Euphorbia* sp. (%3,24), Poaceae (%4,7), *Salix* sp. (%3,58), *Sambucus ebulus* (%5,59), *Tilia* sp. (%3,46)	*Anthemis* sp. (%0,45), *Carex* sp. (%0,67), *Cichorium intybus* (%0,67), *Cistus* sp. (%0,45), *Cucurbita* sp. (%0,11), *Cupressus* sp. (%0,22), *Echium vulgare* (%0,56), *Fagus orientalis* (%0,67), Lamiaceae (%0,11), *Ligustrum vulgare* (%0,89), *Malva* sp. (%0,11), *Medicago* sp. (%2,8), *Morus* sp. (%0,22), *Pinus* sp. (%0,11), *Plantago* sp. (%0,45), *Populus* sp. (%0,11), *Potentilla* sp. (%1,347), *Prunus* sp. (%0,22), *Quercus* sp. (%0,78), Ranunculaceae (%0,89), *Rhododendron ponticum* (%0,11), *Rorippa* sp. (%2,8), *Rosa canina* (%1,68), *Rubus* sp. (%1,9), *Rumex* sp. (%0,11) ve *Trifolium* sp. (%1,79)	33
Ç2		*Castanea sativa* (%28,46)	Apiaceae (%5,52), Brassicaceae (%5,7), *Medicago* sp. (%5,87), Poaceae (%7,11), Ranunculaceae (%3,38), *Rubus* sp. (%4,63), *Salix* sp. (%3,38), *Sambucus ebulus* (%6,94), *Tilia* sp. (%4,8), *Trifolium* sp. (%6,76)	*Alnus* sp. (%0,18), *Carex* sp. (%0,71), *Cichorium intybus* (%1,42), *Carduus* sp. (%0,18), *Dipsacus* sp. (%0,18), *Echium vulgare* (%0,71), *Euphorbia* sp. (%0,18), *Fagus orientalis* (%1,78), *Ilex aquifolium* (%0,35), *Lathyrus* sp. (%0,71), Lamiaceae (%0,35), *Malva* sp. (%0,18), *Morus* sp. (%0,18), *Plantago* sp. (%2,49), *Potentilla* sp. (%0,17), *Quercus* sp. (%1,24), *Rhododendron ponticum*(%0,35), *Rorippa* sp. (%2,49), *Rosa canina* (%2,31) ve *Rumex* sp. (%0,71)	31
Ç3		*Castanea sativa* (%34,93), *Rubus* sp. (%16,59)	Apiaceae (%9,17), *Cornus* sp. (%7,86), Poaceae (%3,05), *Rosa canina* (%10,48), *Rumex* sp. (%3,05)	*Cichorium intybus* (%1,75), *Cupressus* sp. (%0,87), *Echium vulgare* (%0,87), *Epilobium* sp. (%0,44), *Euphorbia* sp. (%0,44), *Helianthus annuus* (%0,44), *Iris* sp. (%0,44), *Lotus* sp. (%0,87), *Medicago* sp. (%2,18), *Pinus* sp. (%0,44), *Plantago* sp. (%1,31), Ranunculaceae (%1,31), *Rhododendron ponticum* (%2,18), *Sambucus ebulus* (%0,44), *Saponaria* sp. (%0,44) ve *Tilia* sp. (%0,44)	23
G1		Apiaceae (%18,28), *Castanea sativa* (%37,43), *Rhododendron ponticum* (%14,76)	*Pinus* sp. (%4,22), Rosaceae (%4,57), *Rumex* sp. (%3,34)	*Allium cepa* (%0,7), Asteraceae (%0,35), Brassicaceae (%0,35), *Carduus* sp. (%0,52), Caryophyllaceae (%0,35), Convolvulaceae (%0,35), *Cornus* sp. (%1,05), *Cupressus* sp. (%1,05), *Echium vulgare* (%0,35), *Elaeagnus angustifolia* L. (%0,17), *Ilex aquifolium* (%1,76), Lamiaceae (%0,17), *Lathyrus* sp. (%1,76), *Medicago* sp. (%1,4), *Geranium* sp. (%0,17), *Papaver* sp. (%0,17), *Plantago* sp. (%0,35), Poaceae sp. (%2,46), *Salix* sp. (%0,87) ve *Taraxacum* sp. (%2,99)	26
G2		Rosaceae (%31,92), *Taraxacum* sp. (%30,13)	Apiaceae (%6,78), *Castanea sativa* (%5,34), Poaceae (%7,4)	*Alnus* sp. (%0,06), *Arctium minus* (%0,82), Boraginaceae (%0,75), Brassicaceae (%0,89), *Carduus* sp. (%0,06), *Cota tinctoria* var. *pallida* (%1,3), *Cornus* sp. (%1,37), *Cupressus* sp. (%0,55), *Echium vulgare* (%0,06), *Fagus orientalis*	31

				(%1,09), *Geranium* sp. (%0,2), *Hedysarum* sp. (%0,34), *Ilex aquifolium* (%2,46), *Juglans regia* (%0,61), *Lathyrus* sp. (%0,55), *Laurus nobilis* (%0,61), Loranthaceae (%0,27), *Medicago* sp. (%0,96), *Pinus* sp. (%0,13), *Plantago* sp. (%0,06), *Quercus* sp. (%1,71), Ranunculaceae (%0,41), *Rhododendron ponticum* (%0,34), *Rumex* sp. (%0,48), *Tilia* sp. (%0,06), *Trifolium* sp. (%2,19)	
G3	*Castanea sativa* (%58,49)		Apiaceae (%6,1), *Plantago* sp. (%7,88), *Taraxacum* sp. (%5,8)	*Acer* sp. (%0,61), Asteraceae (%0,1), *Asperula* sp. (%0,05), Betulaceae (%0,05), Brassicaceae (%0,45), *Carduus* sp. (%0,4), *Cornus* sp. (%1,27), *Crateagus* sp. (%0,25), *Cupressus* sp. (%0,1), *Echium vulgare* (%0,76), *Epilobium* sp. (%0,15), Fabaceae (%0,61), *Fagus orientalis* (%0,2), *Geranium* sp. (%0,05), *Hedysarum* sp. (%0,25), *Ilex aquifolium* (%0,3), *Iris* sp. (%0,05), *Juglans regia* (%0,25), Lamiaceae (%0,35), *Lathyrus* sp. (%0,05), *Laurus nobilis* (%0,1), *Ligustrum vulgare* (%0,2), *Medicago* sp. (%1,53), *Pinus* sp. (%0,2), Poaceae (%1,27), *Prunus* sp. (%0,15), *Pyracantha coccinea* (%0,61), *Quercus* sp. (%1,32), *Ranunculus* sp. (%1,78), Rhamnaceae (%0,05), *Rhododendron ponticum* (%0,15), *Rosa canina* (%1,01), *Rumex* sp. (%1,42), *Stachys* sp. (%0,25), *Tilia* sp. (%1,53) ve *Trifolium* sp. (%2,95)	40
G4		*Rhododendron ponticum* (%18,2), *Taraxacum* sp. (%17,43)	Apiaceae (%11,28), Brassicaceae (%4,35), *Castanea sativa* (%12,3), *Helianthus annuus* (%5,12), Rosaceae (%6,41), *Rumex* sp. (%3,07), *Salix* sp. (%6,41)	*Acer* sp. (%0,51), *Ilex aquifolium* (%2,3), *Alnus* sp. (%1,02), Boraginaceae (%0,26), Caryophyllaceae (%0,51), Caprifoliaceae (%0,51), *Centaurea* sp. (%0,26), *Clematis* sp. (%0,51), *Cornus* sp. (%1,79), *Echium vulgare* (%0,26), Lamiaceae (%0,51), Loranthaceae (%0,26), *Pinus* sp. (%1,28), *Plantago* sp. (%0,26), Poaceae (%2,3) ve *Zinnia* sp. (%1,28)	25
G5	*Castanea sativa* (%80,47)		*Rubus* sp. (%5,68)	Amaranthaceae (Chenopodiaceae) (%0,12), Apiaceae (%2,48), Brassicaceae (%0,35), *Cichorium intybus* (%0,35), *Cornus* sp. (%1,42), *Echium vulgare* (%1,66), *Helianthus annuus* (%0,35), *Pinus* sp. (%0,12), *Plantago* sp. (%0,24), Poaceae (%2,37), *Potentilla* sp. (%1,42), *Quercus* sp. (%0,24), *Rhododendron ponticum* (%0,83), *Rosa canina* (%0,71), *Rumex* sp. (%0,12), *Tilia* sp. (%0,35) ve *Trifolium* sp. (%0,71)	19
Gü1	*Castanea sativa* (%56,3)		Apiaceae (%4,36), Brassicaceae (%4,36), *Crateagus* sp. (%5,21), *Rosa canina* (%3,8), *Rubus* sp. (%3,94), *Trifolium* sp. (%4,9)	*Allium cepa* (%0,14), *Alnus* sp. (%0,42), *Bellis* sp. (%0,28), *Cistus* sp. (%0,85), Convolvulaceae (%0,7), *Dipsacus* sp. (%0,28), *Echium vulgare* (%0,42), Ericaceae (%2,4), *Fagus orientalis* (%0,98), *Isatis* sp. (%0,28), *Juglans regia* (%0,14), Lamiaceae (%0,14), *Laurus nobilis* (%0,84), *Ligustrum*	29

				vulgare (%0,14), *Medicago* sp. (%2,95), *Plantago* sp. (%0,84), Poaceae (%0,28), *Quercus* sp. (%2,95), *Sanguisorba* sp. (%0,14), *Scabiosa* sp. (%0,56), *Taraxacum* sp. (%0,7) ve *Tilia* sp. (%0,56)	
Gü 2		*Castanea sativa* (%29,7), *Crateagus* sp. (%8,82), Fabaceae (%28)	Ericaceae (%15,8), *Rosa canina* (%3,78)	Amaranthaceae (Chenopodiaceae) (%0,56), Apiaceae (%1,96), *Cichorium intybus* (%0,7), *Cirsium* sp. (%0,14), *Cistus* sp. (%3,36), *Echium vulgare* (%0,56), *Geranium* sp. (%0,28), Lamiaceae (%0,14), *Ligustrum vulgare* (%1,12), *Plantago* sp. (%0,84), Poaceae (%0,7), *Quercus* sp. (%1,68), *Scabiosa* sp. (%0,56) ve *Tilia* sp. (%1,26)	19
K1	*Castanea sativa* (%69,25)		Apiaceae (%9,32), *Quercus* sp. (%3,89)	Amaranthaceae (Chenopodiaceae) (%0,05), *Arctium minus* (%0,47), Betulaceae (%0,43), *Brassica* sp. (%0,53), *Cirsium* sp. (%0,21), *Cistus* sp. (%0,05), *Cichorium intybus* (%1,97), *Crateagus* sp. (%0,69), *Convolvulus* sp. (%0,1), *Cornus* sp. (%0,64), *Cupressus* sp. (%0,05), *Echium vulgare* (%0,37), *Fagus orientalis* (%0,05), *Geranium* sp. (%0,05), *Helianthus annuus* (%1,43), *Lathyrus* sp. (%0,32), *Laurus nobilis* (%0,05), *Ligustrum vulgare* (%0,64), *Medicago* sp. (%1,22), *Pinus* sp. (%0,05), *Plantago* sp. (%0,27), Poaceae (%1,28), *Potentilla* sp. (%0,32), *Rorippa* sp. (%0,05), *Rosa canina* (%1,33), *Rubus* sp. (%0,27), *Salix* sp. (%0,8), *Salvia* sp. (%0,16), *Sambucus ebulus* (%0,96), *Scabiosa* sp. (%0,21), *Tilia* sp. (%1,49) ve *Trifolium* sp. (%0,96)	35
K2			*Arctium minus* (%3,84), *Brassica* sp. (%4,3), *Castanea sativa* (%14,9), *Cornus* sp. (%5,53), *Lathyrus* sp. (%3,68), *Ligustrum vulgare* (%15,2), *Rorippa* sp. (%6,14), *Salix* sp. (%7,37), *Sambucus ebulus* (%9,67), *Trifolium* sp. (%4,14)	*Alnus* sp. (%0,15), Apiaceae (%1,67), *Cota tinctoria* var. *pallida* (%0,46), *Cupressus* sp. (%0,3), *Dipsacus* sp. (%2,92), *Echium vulgare* (%0,3), *Fagus orientalis* (%0,15), *Geranium* sp. (%2,3), *Hedera helix* L. (%0,15), *Helianthus annuus* (%0,15), Lamiaceae (%0,15), *Laurus nobilis* (%0,92), Myrtaceae (%0,15), *Onobrychis* sp. (%1,38), *Pinus* sp. (%0,15), *Plantago* sp. (%0,61), Poaceae (%1,22), *Quercus* sp. (%2,3), *Rhododendron ponticum* (%2,92), *Rumex* sp. (%0,15), *Saponaria* sp. (%0,3) ve *Taraxacum* sp. (%2,15)	32
K3	*Castanea sativa* (%86,3)			Apiaceae (%1,77), *Centaurea* sp. (%0,12), *Cichorium intybus* (%0,12), *Crateagus* sp. (%0,94), *Cornus* sp. (%0,12), *Echium vulgare* (%1,41), *Fagus orientalis* (%0,12), *Helianthus annuus* (%1,77), *Lathyrus* sp. (%1,18), *Onobrychis* sp. (%0,12), Poaceae (%0,24), *Potentilla* sp. (%0,24), *Rhododendron ponticum* (%0,12), *Rorippa* sp. (%0,12), *Rosa canina* (%1,41),	20

				Rubus sp. (%0,47), *Salix* sp. (%1,06), *Tilia* sp. (%0,24) ve *Trifolium* sp. (%2,12)	
K4	*Castanea sativa* (%86,3)			Apiaceae (%0,43), *Brassica* sp. (%0,43), *Cornus* sp. (%0,5), *Dipsacus* sp. (%0,07), *Echium vulgare* (%1,15), *Fagus orientalis* (%0,21), *Galega* sp. (%0,57), *Helianthus annuus* (%1,15), *Hypericum* sp. (%0,14), *Juglans regia* (%0,14), *Ligustrum vulgare* (%0,72), *Medicago* sp. (%0,43), *Onobrychis* sp. (%0,21), *Plantago* sp. (%0,07), Poaceae (%0,43), *Potentilla* sp. (%0,07), *Ranunculus* sp. (%0,29), *Rhododendron ponticum* (%0,36), *Rosa canina* (%2,88), *Rubus* sp. (%1,44), *Salix* sp. (%0,72), *Sambucus ebulus* (%0,29), *Tilia* sp. (%0,14) ve *Trifolium* sp. (%0,86)	25
K5	*Castanea sativa* (%80,2)			*Alnus* sp. (%0,05), Amaranthaceae (Chenopodiaceae) (%0,11), Apiaceae (%0,94), *Bidens* sp. (%0,55), *Centaurea* sp. (%0,17), *Clematis* sp. (%0,5), *Cota tinctoria* var. *pallida* (%0,22), *Cornus* sp. (%0,77), *Cupressus* sp. (%0,05), *Echium vulgare* (%0,99), *Fagus orientalis* (%0,05), *Geranium* sp. (%0,05), *Hedysarum* sp. (%0,17), *Helianthus annuus* (%1,82), *Medicago* sp. (%1,99), Moraceae (%0,05), *Plantago* sp. (%0,11), Poaceae (%0,55), *Potentilla* sp. (%0,66), *Prunus* sp. (%0,11), *Quercus* sp. (%3,09), Rhamnaceae (%0,05), *Rhododendron ponticum* (%0,16), *Rorippa* sp. (%0,22), *Rosa canina* (%1,99), *Rubus* sp. (%1,66), *Rumex* sp. (%0,22), *Salix* sp. (%0,22), *Sambucus ebulus* (%0,66), *Scabiosa* sp. (%0,05), Solanaceae (%0,05), *Stachys* sp. (%0,17), *Tilia* sp. (%0,05) ve *Trifolium* sp. (%1,22)	35
M1		*Castanea sativa* (%35,5)	Apiaceae (%8,82), *Brassica* sp. (%8,82), *Medicago* sp. (%11), *Plantago* sp. (%3,68), Poaceae (%7,35), *Rosa canina* (%8,82)	*Ailanthus* sp. (%1,47), *Clematis* sp. (%2,94), *Echium vulgare* (%0,73), Ericaceae (%0,73), Papaveraceae (%2,94), *Rumex* sp. (%1,47), *Rorippa* sp. (%2,2), *Taraxacum* sp. (%0,73), *Tilia* sp. (%2,2) ve *Zinnia* sp. (%0,73)	17
M2		*Calystegia* sp. (%27,66)	Apiaceae (%12,88), *Castanea sativa* (%5,08), Ericaceae (%4,96), *Fagus orientalis* (%9,93), *Plantago* sp. (%8,63), *Pyracantha coccinea* (%3,3), *Rosa canina* (%5,9), *Rubus* sp. (%4,02)	*Alnus* sp. (%0,94), Amaranthaceae (Chenopodiaceae) (%0,23), *Bellis* sp. (%0,23), Boraginaceae (%0,23), Brassicaceae (%0,7), *Carduus* sp. (%0,7), *Centaurea* sp. (%1,42), *Cistus* sp. (%0,94), *Cota tinctoria* var. *pallida* (%0,12), *Corylus* sp. (%1,89), *Cupressus* sp. (%0,12), *Echium vulgare* (%0,12), *Ilex aquifolium* (%0,12), Papaveraceae (%0,23), *Pinus* sp. (%2), Poaceae (%0,7), *Populus* sp. (%0,12), *Quercus* sp. (%1,06), Ranunculaceae (%1,77), *Rhododendron ponticum* (%0,35),	33

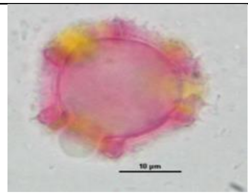
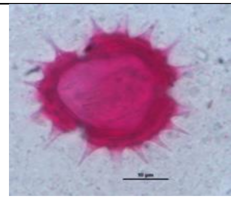
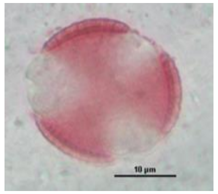
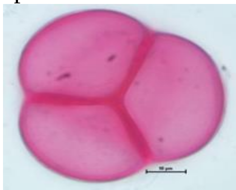
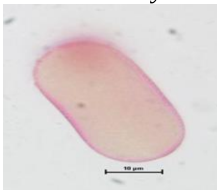
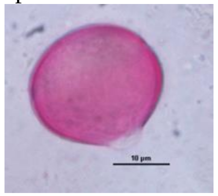
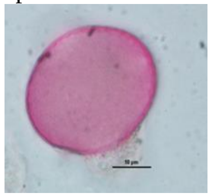
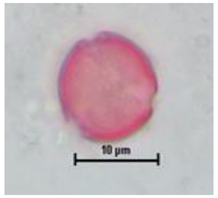
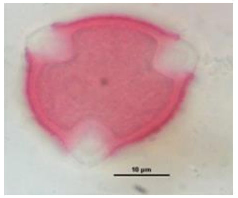
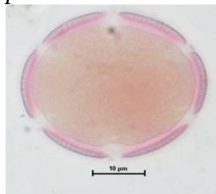
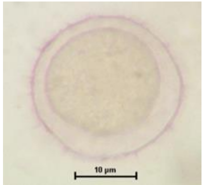
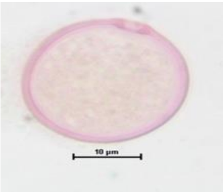
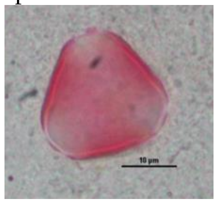
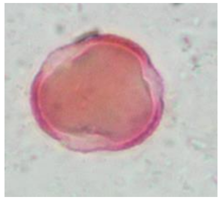
			Salix sp. (%0,35), *Taraxacum* sp. (%2,84), *Trifolium* sp. (%0,23) ve *Zinnia* sp. (%0,12)	
M3	*Castanea sativa* (%47,38)	Apiaceae (%6,96), *Corylus* sp. (%3,63), *Fagus orientalis* (%8,47), *Plantago* sp. (%3,12), Poaceae (%10,18), *Tilia* sp. (%6,25)	*Alnus* sp. (%1,5), Amaranthaceae (Chenopodiaceae) (%0,5), *Bellis* sp. (%0,9), *Calystegia* sp. (%0,5), *Centaurea* sp. (%0,2), *Cistus* sp. (%1,8), *Cupressus* sp. (%0,1), *Echium vulgare* (%0,1), Ericaceae (%0,3), *Ilex aquifolium* (%0,1), Lamiaceae (%0,1), *Ligustrum vulgare* (%0,2), *Pinus* sp. (%0,8), *Populus* sp. (%1,6), *Quercus* sp. (%1,81), Ranunculaceae (%1,7), *Rhododendron ponticum* (%0,1), *Rumex* sp. (%1,3) ve *Taraxacum* sp. (%0,3)	26
M4	*Ailanthus* sp. (%67,6) *Helianthus annuus* (%22,06)		Apiaceae (%0,34), *Bidens* sp. (%0,78), Brassicaceae (%0,7), *Carduus* sp. (%0,086), *Castanea sativa* (%2,78), *Centaurea* sp. (%0,086), *Cichorium intybus* (%0,17), *Cistus* sp. (%1,39), *Echium vulgare* (%0,17), *Epilobium* sp. (%0,086), *Geranium* sp. (%0,17), *Hedysarum* sp. (%0,086), Lamiaceae (%0,26), *Plantago* sp. (%0,086), Poaceae (%1,04), *Rumex* sp. (%0,086), *Trifolium* sp. (%0,26) ve *Zinnia* sp. (%0,6)	20
Y1	*Castanea sativa* (%55,87)	Brassicaceae (%10,26), *Fagus orientalis* (%3,48), *Onobrychis* sp. (%3,88)	*Allium cepa* (%0,34), Apiaceae (%2,74), *Asperula* sp. (%0,17), Betulaceae (%0,05), *Centaurea* sp. (%0,05), *Cirsium* sp. (%0,11), *Cistus* sp. (%0,34), *Convolvulus* sp. (%1,02), *Cornus* sp. (%1,14), *Cupressus* sp. (%0,11), *Echium vulgare* (%1,42), *Eupatorium* sp. (%0,17), *Elaeagnus angustifolia* (%0,22), *Geranium* sp. (%0,11), *Hedysarum* sp. (%1,31), *Helianthus annuus* (%0,17), *Lactuca* sp. (%0,34), Lamiaceae (%1,25), *Lathyrus* sp. (%0,62), *Laurus nobilis* (%0,05), *Ligustrum vulgare (*%2,62), *Medicago* sp. (%0,28), *Pinus* sp. (%0,22), *Plantago* sp. (%1,31), Poaceae (%1,48), *Prunus* sp. (%0,11), *Pyracantha coccinea* (%0,57), *Ranunculus* sp. (%0,57), *Rhododendron ponticum* (%0,91), *Rorippa* sp. (%0,96), *Rosa canina* (%0,46), *Rumex* sp. (%0,28), *Rubus* sp. (%0,28), *Salix* sp. (%2,28), *Sambucus ebulus* (%0,11), *Sanguisorba* sp. (%0,05), *Scabiosa* sp. (%0,05), *Stachys* sp. (%0,28), *Tilia* sp. (%1,31) ve *Trifolium* sp. (%1,82)	44
Y2	*Rhododendron ponticum* (%55,2)	*Acer* sp. (%4,52), *Castanea sativa* (%13,55), *Fagus orientalis* (%4,14), *Medicago* sp. (%5,14), *Pinus* sp. (%4,01), *Quercus* sp. (%5,9)	*Allium cepa* (%1), *Alnus* sp. (%1), Apiaceae (%0,5), Betulaceae (%0,12), *Cichorium intybus* (%0,12), *Cirsium* sp. (%0,25), *Cornus* sp. (%0,25), *Cota tinctoria* var. *pallida* (%0,12), *Cupressus* sp. (%0,12), *Geranium* sp. (%0,25), *Ilex aquifolium* (%0,25), *Juglans regia* (%0,12), *Ligustrum vulgare* (%0,25), Poaceae (%0,12), *Pyracantha coccinea* (%1,13), *Rosa canina*	26

				(%0,75), *Rubus* sp. (%0,38), *Salix* sp. (%1,5) ve *Sambucus ebulus* (%0,12)	
Y3	*Castanea sativa* (%53,65)	*Quercus* sp. (%20,18)	*Brassica* sp. (%6,11), *Sambucus ebulus* (%3,18)	Apiaceae (%0,76), *Agrimonia sp.* (%0,23), *Alnus* sp. (%0,05), *Astragalus* sp. (%0,59), *Ailanthus* sp. (%0,05), *Campanula* sp. (%0,05), *Crateagus* sp. (%0,59), *Celtis* sp. (%0,12), *Cichorium intybus* (%0,94), *Convolvulus* sp. (%0,94), *Cota tinctoria* var. *pallida* (%0,05), *Cupressus* sp. (%0,05), Betulaceae (%0,18), *Fagus orientalis* (%0,18), *Geranium* sp. (%0,18), *Helianthus annuus* (%0,05), *Iris* sp. (%0,05), *Lapsana* sp. (%1,94), *Ligustrum vulgare* (%0,47), *Matthiola* sp. (%0,12), *Medicago* sp. (%1,05), *Melissa officinalis* L. (%0,05), *Plantago* sp. (%0,41), Poaceae (%0,65), *Pyracantha coccinea* (%0,7), *Rhododendron ponticum* (%0,18), *Rorippa* sp. (%1,47), *Salix* sp. (%2,12), *Salvia* sp. (%0,05), *Taraxacum* sp. (%0,12), *Tilia* sp. (%0,53) ve *Trifolium* sp. (%1,35)	36
Y4		*Erica* sp. (%28,7), *Fagus orientalis* (%26,1)	*Rhododendron ponticum* (%12,8), *Rosa canina* (%4,83), *Salix* sp. (%11,5)	*Acer* sp. (%0,64), *Allium cepa* (%0,21), *Ilex aquifolium* (%0,32), Betulaceae (%0,21), *Castanea sativa* (%1,5), *Cichorium intybus* (%0,1), *Cirsium* sp. (%0,1), *Cota tinctoria* var. *pallida* (%0,1), *Crataegus* sp. (%2,04), *Cupressus* sp. (%0,1), *Geranium* sp. (%0,64), *Juglans regia* (%0,1), *Medicago* sp. (%1,5), *Laurus nobilis* (%0,1), *Pinus* sp. (%0,75), *Plantago* sp. (%1,61), Poaceae (%0,1), *Pyracantha coccinea* (%2,68), *Salvia* sp. (%0,21), *Sambucus ebulus* (%1,29), *Trifolium* sp. (%1,61) ve *Urtica dioica* L. (%0,1)	27
Y5	*Castanea sativa* (%87,32)			*Allium cepa* (%0,08), Apiaceae (%0,17), *Astragalus* sp. (%0,08), *Centaurea* sp. (%0,08), *Cichorium intybus* (%0,26), *Cornus* sp. (%0,51), *Echium vulgare* (%0,34), *Hedysarum* sp. (%0,17), *Fagus orientalis* (%1,88), Lamiaceae (%0,34), *Medicago* sp. (%0,05), *Papaver* sp. (%0,08), *Plantago* sp. (%0,43), Poaceae (%0,08), *Potentilla* sp. (%0,17), *Quercus* sp. (%0,08), Rhamnaceae (%0,08), *Rhododendron ponticum* (%1,37), *Rosa canina* (%1,03), Rosaceae (%1,28), *Rumex* sp. (%0,08), *Salix* sp. (%1,03), *Scabiosa* sp. (%0,17), Solanaceae (%0,08) ve *Trifolium* sp. (%0,6)	26
Y6	*Rhododendron ponticum* (%60)		*Castanea sativa* (%4,3), *Erica* sp. (%5,04), *Heliotropium* sp. (%5,9), *Rosa canina* (%3,56), *Sambucus ebulus* (%5,04)	*Acer* sp. (%0,74), *Alnus* sp. (%0,24), Apiaceae (%0,12), *Centaurea* sp. (%0,12), *Cota tinctoria* var. *pallida* (%0,12), *Cichorium intybus* (%0,37), *Crataegus* sp. (%1,23), *Fagus orientalis* (%0,12), *Ilex aquifolium* (%0,98), *Ligustrum vulgare* (%1,84), *Lotus* sp. (%0,24), *Medicago* sp. (%1,84), *Pinus* sp.	24

			(%0,37), *Rorippa* sp. (%1,23), *Rubus* sp. (%1,71), *Pyracantha coccinea* (%0,86), *Salix* sp. (%2,09) ve *Trifolium* sp. (%1,47)	
Y7	*Rhododendron ponticum* (%51,47)	*Brassica* sp. (%5,37), *Castanea sativa* (%7,65), *Cistus* sp. (%7,13), *Erica* sp. (%12,28)	*Allium cepa* (%0,15), Apiaceae (%0,51), *Carduus* sp. (%0,15), *Cichorium intybus* (%0,07), *Convolvulus* sp. (%0,15), *Cota tinctoria* var. *pallida* (%0,15), *Crataegus* sp. (%1,54), *Fagus orientalis* (%2,35), *Geranium* sp. (%0,37), *Helianthus annuus* (%0,44), *Ilex aquifolium* (%0,44), *Lathyrus* sp. (%0,73), Lamiaceae (%0,15), *Medicago* sp. (%0,59), *Pinus* sp. (%0,8), *Plantago* sp. (%0,22), Poaceae (%0,37), *Populus* sp. (%0,22), *Pyracantha coccinea* (%2,57), *Rorippa* sp. (%1,47), *Rumex* sp. (%0,22), *Rubus* sp. (%0,95), *Salix* sp. (%1,32) ve *Trifolium* sp. (%0,88)	29

A: Akçakoca, C: Cumayeri, Ç: Çilimli, G: Gölyaka, Gü: Gümüşova, K: Kaynaşlı, M: Merkez, Y: Yığılca

Tablo 2. Düzce yöresi ballarında tespit edilen polenlerin mikrofotoğrafları.

 Adoxaceae – *Sambucus ebulus*	 Apiaceae	 Asteraceae – *Artemisia* sp.	 Asteraceae – *Carduus* sp.	 Asteraceae – *Cichorium intybus*	 Asteraceae – *Zinnia* sp.	 Betulaceae – *Alnus* sp.
 Brassicaceae	 Caprifoliaceae – *Scabiosa* sp.	 Ericaceae – *Erica sp.*	 Ericaceae – *Rhododendron ponticum*	 Fabaceae – *Onobrychis* sp.	 Fabaceae – *Medicago* sp.	 Fabaceae – *Trifolium* sp.
 Fagaceae – *Castanea sativa*	 Fagaceae – *Fagus orientalis*	 Fagaceae – *Quercus* sp.	 Lamiaceae - *Salvia* sp.	 Lauraceae – *Laurus nobilis*	 Oleaceae – *Ligustrum vulgare*	 Pinaceae – *Pinus*
 Poaceae	 Polygonaceae – *Rumex* sp.	 Rosaceae – *Potentilla* sp.	 Rosaceae – *Rosa canina*	 Salicaceae – *Salix* sp.	 Simaroubaceae – *Ailanthus* sp.	 Tiliaceae – *Tilia tomentosa*

Tartışma

Düzce merkez ve 7 ilçesinden (Akçakoca, Cumayeri, Çilimli, Gölyaka, Gümüşova, Kaynaşlı, Yığılca) temin edilen 34 bal örneğinin yapılan analizler sonucunda 12 bal örneğinin monofloral ve geri kalan 22 bal örneğinin polifloral bal olduğu tespit edilmiştir. Çalışmamızda dominant düzeyde temsil edilen taksonların *Ailanthus altissima, Castanea sativa* ve *Rhododendron ponticum* olduğu belirlenmiştir.

Sorkun ve Doğan (1995), yılında yapmış oldukları çalışmada dominant gruptaki takson çeşitliliğinin her zaman daha az, eser gruptaki takson çeşitliliğinin ise daha fazla olduğunu bildirmiştir. Düzce yöresi ballarında yapmış olduğumuz polen analizi çalışmasının sonucu bu literatür bilgisine uygunluk göstermektedir.

Güneş Özkan vd. (2016) yılında yapmış olduğu Hasanlar Barajı (Düzce - Yığılca) ve Çevresinin Ballı Bitkileri adlı çalışmada en yüksek düzeyde tespit edilen familyaların Fabaceae, Asteraceae ve Rosaceae olduğunu tespit etmişlerdir. Yıldırım (2020) tarafından aynı bölgede yapılan Yığılca Yöresi Ballarının Polen Analizi ve Ballı Bitkiler Florası çalışmasında en çok görülen familyaların Asteraceae, Rosaceae ve Fabaceae olduğu belirlenmiştir. İki çalışma sonucu karşılaştırıldığında aynı familyaların kendi çalışmamızda da en yüksek oranda tespit edildiği görülmüştür ve Yığılca bölgesinden elde edilen balların bitki florasıyla uygunluk gösterdiği belirlenmiştir.

Bölgede lokal ölçekte Yığılca ilçesinin balları üzerine iki çalışma yapılmıştır. Kambur vd. (2015), yapmış oldukları çalışma kapsamında inceledikleri 10 bal numunesinden 3'ünü monofloral ve geri kalan 7'sini polifloral bal olarak tanımlamıştır. Çalışma kapsamında 15 taksonun poleni teşhis edilmiştir. Dominant gruptaki polenlerin *Castanea sativa* ve *Rhododendron ponticum* olduğu belirlenmiştir. Çalışmamızın Yığılca örnekleriyle karşılaştırıldığı zaman dominant düzeydeki polen taksonlarının benzer olduğu gözlenmiştir.

Yıldırım (2020), yapmış olduğu çalışma kapsamında incelediği 7 bal örneğinin 2 tanesini monofloral geri kalan 5 tanesini polifloral bal olarak tanımlamıştır. Çalışma kapsamında 42 taksonun poleni teşhis edilmiştir. Dominant gruptaki polenlerin *Castanea sativa* ve *Rhododendron ponticum* olduğu belirlenmiştir. Çalışmamızın Yığılca örnekleriyle karşılaştırıldığı zaman dominant olarak tespit edilen taksonların benzer olduğu görülmüştür bununla birlikte *Agrimonia repens*, Apiaceae, *Arctium minus*, *Campanula* sp., *Centaurea* sp., *Cirsium* sp., *Cota tinctoria* var. *pallida*, *Crateagus* sp., *Cupressus* sp., *Echium vulgare*, *Fagus orientalis*, *Geranium* sp., *Ligustrum vulgare*, *Plantago* sp., *Potentilla* sp., *Pyracantha coccinea*, *Quercus* sp., *Rosa canina*, *Rubus* sp., *Salvia* sp., *Sambucus ebulus*, *Stachys* sp., *Trifolium* sp. ve *Urtica dioica* L. taksonları her iki çalışmada da tespit edilmiştir. Bunların dışında kalan taksonlar çalışmamızda familya ve cins düzeyinde görülmüştür.

06.09.2021 tarihinde Düzce İl Tarım ve Orman Müdürlüğü tarafından tescil ettirilen Düzce Kestane Balının içerisinde barındırması gereken polen oranı en az %70 olarak belirtilmiştir (Anonim, 2021). Yapmış olduğumuz çalışma kapsamında 8 bal örneği *Castanea sativa* (kestane) balı olarak belirlenmiştir. Kestane balı olarak adlandırılan numuneler Cumayeri 1 (% 74,8), Cumayeri 2 (% 81,26), Cumayeri 3 (% 74,84), Gölyaka 5 (% 80,47), Kaynaşlı 3 (% 86,3), Kaynaşlı 4 (% 86,26), Kaynaşlı 5 (% 80,2) ve Yığılca 5 (% 87,32) numaralı bal örneklerine aittir. Çalışma sonucumuza baktığımız zaman Kestane balı olarak adlandırılan örneklerin tescil belgesiyle uyum sağladığı gözlenmiştir.

Erdoğan (2007), yılında yaptığı Sakarya ili ve on iki ilçesini kapsayan çalışmasında 65 bal örneği temin etmiştir. Analizler sonucunda 11 bal örneğinin monofloral, 54 bal örneğinin polifloral bal olduğunu tespit etmiştir. Çalışma kapsamında 51 taksonun poleni teşhis edilmiştir. Dominant gruptaki polenlerin *Castanea sativa*, *Cistus* sp., *Cynoglossum* sp., Fabaceae, *Hedysarum* sp., Ranunculaceae, Rhamnaceae, *Rhododendron* sp., Rosaceae, Scrophulariaceae ve *Xanthium* sp. taksonlarına ait olduğu belirlenmiştir. Fagaceae familyasından *Castanea sativa*'nın her iki çalışmada dominant özellik göstermesinin sebebi yörenin doğal bitkilerinden biri olması ve geniş yayılışa sahip olmasıyla açıklanabilir.

Fişne (2016), yılında yaptığı çalışma kapsamında 85 bal örneğini incelemiştir ve bu örneklerin 4'ünü monofloral kestane balı olarak tanımlamıştır. Çalışmada dominant düzeyde tespit edilen taksonların *Castanea sativa* ve Lamiaceae olduğu belirlenmiştir. Bizim çalışmamızda olduğu gibi *Castanea sativa* bal örneklerinde en çok gözlenen taksondur bunun sebebi bölgenin doğal bitkilerinden olması ve geniş yayılışa sahip olmasıyla açıklanabilir. Çalışmamızla benzerlik gösteren bir diğer takson istilacı bir tür olarak karşımıza çıkan *Ailanthus* sp. polenleridir ve bu çalışmanın iki örneğinde karşımıza çıkmaktadır.

Daha önceki çalışmalarla karşılaştırıldığında *Ailanthus sp.* poleni 2 çalışmada minör ve eser düzeyde karşımıza çıkmıştır (Özler, 2015; Fişne, 2016). Bizim çalışmamızda *Ailanthus altissima* taksonuna ait polenler dominant düzeydedir ve *Ailathus* balı olarak tanımlanmıştır. Dolayısıyla bu örnek *Ailathus* balı için ilk kayıt olabilir.

Bakoğlu vd. (2014) yılında Bingöl ilinde yaptıkları çalışma kapsamında 5 bal örneği incelemişlerdir. Çalışma sonucunda *Thymus leucostomus, Astragalus lagurus, Tribulus terrestris, Echinacea purpurea* ve *Lamium purpureum* taksonları dominant, sekonder ve minör düzeyde tespit edilmiştir.

Bayramlı vd. (2016), yılında yaptıkları çalışma kapsamında 10 bal örneği incelemişler ve toplamda 34 polen taksonu tanımlamışlardır. Dominant düzeyde tespit edilen taksonların Liliaceae ve *Medicago* sp. olduğu belirlenmiştir.

Sülün vd. (2017), 2013 yılında Kars ili ve beş ilçesinden temin ettikleri 6 bal örneği ve 5 polen granülü üzerinde çalışmışlardır. Bal örneklerinde 21 polen taksonu tespit edilmiş ve dominant taksonların Compositea (Asteraceae), Leguminosea (Fabaceae) ve *Mercurialis* sp. olduğu belirlenmiştir. Düzce yöresinde yapmış olduğumuz çalışma ile karşılaştırıldığı zaman son üç çalışmanın dominant polen düzeyinde benzerlik görülmemiştir. Ülkemiz üç fitocoğrafik bölgenin kesiştiği konumda yer almasından kaynaklı zengin bitki çeşitliliğine sahiptir. Bu nedenle, farklı coğrafi bölgelere ait bal örneklerinde farklı bitki türlerine ait polenler gözlenebilir. Son üç çalışma bu farkı ortaya koymak adına tartışma kısmına eklenmiştir.

Sonuç

Düzce yöresi ballarında 20'si familya, 69'u cins ve 20'si tür düzeyinde toplam 109 taksonun polen teşhisi yapılmıştır. Bal örneklerindeki takson çeşitliliği 17-44 arasında değişmektedir. Çalışma sonucunda sıklıkla karşılaşılan taksonların Apiaceae, Asteraceae, Brassicaceae, Boraginaceae, Ericaceae, Fabaceae, Fagaceae, Plantaginaceae, Poaceae ve Rosaceae, takson çeşitliliği bakımından ise en yoğun familyaların Asteraceae (17), Rosaceae (11) ve Fabaceae (9) olduğu tespit edilmiştir.

Çalışmamızda baskın tür olarak temsil edilen üç takson bulunmaktadır. Bunlardan ilki *Castanea sativa* (17 örnek), ikincisi *Rhododendron ponticum* (3 örnek) ve üçüncüsü *Ailanthus* sp. (1 örnek). Bu taksonlardan *Castanea sativa* ve *Rhododendron ponticum* türlerinin bal örneklerinde görülme sıklığı bölgede doğal yayılış alanlarına sahip olmaları, *Ailanthus altissima* türünün ise örnek temin edilen arılık çevresindeki varlığı ile ilişkilendirilmiştir.

Ailanthus altissima (Cennet ağacı, Kokar ağaç) balı Simaroubaceae familyasından *Ailanthus altissima* monofloral (tek çiçek kaynaklı) bal elde edilebilen, yüksek oranda nektar ve polen içeriğine sahip bir taksondur. Bitkinin adıyla anılan bal aynı zamanda cennet ağacı balı (tree of heaven honey) veya cennet balı (heaven honey) olarak da adlandırılmaktadır (Lixandru, 2017). Bal, kehribar rengindedir ve kovandan alındığı ilk halinde kötü bir tada sahiptir fakat bir müddet dinlendirildikten sonra güzel bir tat almaktadır. Bal aynı zamanda hızlı kristalleşme eğilimindedir (Hu, 1979; Farkas ve Zajacz, 2007; Kowarik ve Saumel, 2007; Thompson, 2008; Gardi, Micheli ve Petrarchini, 2020).

Sekonder grupta temsil edilen polen türleri; *Castanea sativa*, *Rhododendron ponticum*, *Taraxacum* sp., Apiaceae, *Calystegia* sp., *Crateagus* sp., *Erica* sp., Fabaceae, *Fagus orientalis*, *Helianthus annuus*, *Quercus* sp., Rosaceae ve *Rubus* sp. olarak belirlenmiştir. Dominant ve sekonder grupta yer alan polen türleri balın oluşumuna ve isimlendirilmesine birinci derece katkı yaparken, minör ve eser gruptaki polenlerin etkisi daha azdır ve bu grupta yer alan ve çalışmamızda görülen polenlerin (Chenopodiaceae, *Cistus* sp., *Cupressus* sp., *Juglans regia*, *Hypericum* sp., *Morus* sp., *Quercus* sp., *Plantago* sp., Poaceae, *Pinus* sp., *Populus* sp. ve *Rumex* sp.) kontaminasyon sonucu bala katıldığı düşünülmektedir.

Avrupa'da bal ithal eden ülkeler için balın polen içeriği önemli bir kriterdir. Çeşitli mineral maddelere, vitaminlere ve enzimlere sahip olan polenlerin, balda bulunma yüzdeleri melissopalinolojik yöntem ile tespit edilir ve orantılı olarak balın kalitesi artmaktadır (Dalgıç, 1994). Tolon 1999, yılında yapmış olduğu çalışmada kaynağı ve niteliği belli olan balların daha kolay pazarlanabildiğini belirtmiştir. Bazı yerel arıcılar ballarını satışa sunarken balın temin edildiği bölgenin hâkim bitki örtüsünü, tadını, kokusunu ve rengini kriter olarak belirleyip isimlendirmektedir. Fakat bu uygulamanın her zaman doğru sonuç vermeyeceği göz önüne alınarak polen analizleri ile desteklenmesi gerekmektedir.

Düzce yöresinde yapmış olduğumuz çalışma kapsamında arıcılardan temin edilen bal örneklerinin 25 tanesi kestane, 7 tanesi ormangülü ve 2 tanesi çiçek balı olarak kayıt edilmiştir. Yapılan analizler ve uluslararası standartlar göz önüne alındığında temin edilen 25 kestane balı örneğinden 8'inin standartlarla uygunluk gösterdiği (%70 üzeri kestane poleni içermesi) geriye kalan 17 bal örneğinin kestane - çiçek karışık bal olduğu, ormangülü olarak temin edilen 7 örnekten 3 tanesinin %45'in üzerinde *Rhododendron ponticum* poleni içerdiği, çiçek balı olarak temin edilen 2 örnekten birinin çiçek balı, diğerinin ise *Ailanthus altissima* (%67,6) balı olduğu tespit edilmiştir. Analizler sonucunda balın isimlendirilmesi yapılırken polen analizlerinin ne kadar önemli olduğu bir kez daha anlaşılmıştır.

Yaptığımız analizler sonucunda Düzce yöresinin iklim özellikleri ve bitki örtüsünün çeşitliliği arıcılık faaliyeti için uygun olduğu görülmüştür. Kaliteli ve yüksek verimde bal elde etmek isteyen arıcılara kolonilerini çalışma kapsamında tespit edilen nektarlı bitkilerin yoğun olduğu bölgelere taşıması, sabit arıcılık yapıyor ise kovanların etrafına bu bitkilerin ekilmesi önerilebilir. Bu çalışma ülkemizde yapılmış olan melissopalinolojik çalışmaları tamamlayıcı niteliktedir. Çalışmada elde edilen bilgilerin arıcılar ve yöre halkı için faydalı olmasını temenni etmekteyiz.

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Germination characteristics of *Balanites aegyptiaca* (l.) Del. seeds under varying light intensity and sowing orientations in a Sudano-Sahelian zone of Nigeria

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ABSTRACT
Balanites aegyptiaca tree has multiple benefits in the arid/semi-arid regions of Nigeria. However, despite its importance, information on its silvicultural requirements is still scanty. This study was therefore conducted to determine the optimum light requirement and best sowing orientation of *Balanites aegyptiaca* seeds that would enhance its germination. The experiment was laid out in a 4×3 factorial in a Completely Randomized Design (CRD). Factor A (light) has four levels: 100% (L_1), 75% (L_2), 50% (L_3) and 25% (L_4) light intensities. Factor B (sowing orientation) has 3 levels: seeds sown vertically with stalk upward (SO_1), seeds sown vertically with stalk downward (SO_2) and seeds sown horizontally (SO_3). Germination percentage (GP), mean germination time (MGT), and germination speed (GS) were the variables assessed. The results show that light intensity and the interaction between light intensity and sowing orientation did not significantly influence the germination characteristics assessed. However, exposure to 100% light resulted in better GP (13.81±7.18%) and GS (2.85±1.84). Sowing orientation was also found not to affect GP and MGT significantly. However, it affects GS significantly. Sowing seed vertically with stalk upward gave better GP (15.79±6.02%) but early completion of germination (11.29±7.17 days) was observed when seeds were sown horizontally. Seeds sown vertically with stalk upward germinate faster (3.44±1.85). Sowing of *Balanites aegyptiaca* seeds should in a vertical position with their stalk upward and under moderate light exposure is recommended.
Keywords: *Balanites aegyptiaca*, Desert date, Light intensity, Germination percentage, Mean germination time.

INTRODUCTION

Balanites aegyptiaca is a desert or arid/semi-arid specie, it is distributed widely across the Sahel region of Africa, some parts of the Middle East, and Asia (Orwa et al., 2009). It is popularly referred to as desert date because of its similarities with date fruit. It is known as Ádúúwàà in the Northern part of Nigeria where it is common. Identified by its multiple branches and spines, the stem is dark brown or grey colour, while the leaf is green or dark green. It has a height of 10 m and a diameter at breast height of 40 cm at its best (Varshney and Anis, 2014). Various part of the tree is utilized; the fruit and leaf are edible, providing several essential nutrients (Kubmarawa et al., 2008, NRC 2008, Okia et al., 2013). It also has many medicinal benefits (Ojo et al., 2006; Orwa et al., 2009; Morsya et al., 2010; Ya'u et al., 2011; Al-Maliki et al., 2016). The stem is used in constructing farm tools and local slate which is used for writing and reading. The wood of *Balanites aegyptiaca* provides good calorific value when used as fuelwood (Orwa et al., 2009).

Light is one of the most important environmental factors required for seed germination, plant growth, and development (Fankhauser and Chory, 1997; Pons, 2000). According to Menegaes et al, (2018), there are three categories that all seeds belong to: positively photoblastic, negatively photoblastic, and neutral photoblastic. Positively photoblastic seeds germinate in the presence of light, which means they are light-dependent. For example, *Musanga leoerrerae* seeds had the highest germination rate in the presence of light according to Muhanguzi et al. (2002). Negatively photoblastic seeds are inhibited by light, while neutral photoblastic seeds are indifferent to light, for example, species of *Funtumia africana*, *Oxyansus speciosus*, *Funtumia gummifera*, *Celosia argentea*, and *Celosia cristata* did well under neutral light (Muhanguzi et al., 2002; Menegaes et al., 2018). Germination in the seeds of *Cassia fistula*, *Enterolobium saman*, and *Delonix regia* species were found to be significantly affected by light intensity (Aref, 2014). Muhanguzi et al, (2002) also reported a significant difference in the germination response of some selected species. Similarly, Onyekwelu et al. (2012) found a significant difference in the germination of *Chrysophyllum albidum* when exposed to different light intensities. While light intensity was found to affect germination significantly as mentioned earlier, in some species different light regime was found not to affect germination significantly. For example, Onyekwelu et al. (2012) reported that seeds of *Irvingia gabonensis* were not significantly affected by different light treatments. Likewise, Akinyemi and Sakpere (2015) observed that the germination of Moringa seeds was not significantly different between light and dark conditions.

The amount or intensity of light required by the seed during germination is often neglected even though it is an already established fact that the seed of different species responds to light differently during germination (Muhanguzi et al., 2002; Onyekwelu et al., 2012; Aref, 2014; Menegaes et al., 2018). However, the light requirement of several species, especially tropical tree species is yet to be established. It is therefore important to understand the response of specie to light to achieve optimum germination.

Other factors such as sowing orientation or position can also affect germination. Seeds must be placed in a position that allowed the uptake of water and other environmental variables required for germination (Bowers and Hayden 1972). In some instances the effect of sowing orientation on seed germination was reported to be significant (Elfeel, 2012; Zhang et al., 2015) while in another instance it was reported to be non-significant (Kelvin et al., 2015). This implies that the seed of different species responds differently during germination to the position of sowing. The position of the seed during sowing can be vertical or horizontal, depending on the type of seed. For example, in *Balanites aegyptiaca* seeds, better germination was achieved when seeds were sown vertically with stalk downward (Hall and Walker 1991; Sayda 2002; Elfeel, 2012). However, poor germination was reported when seeds of the same *Balanites aegyptiaca* specie were laid in the same position (vertically) according to El Nour and Kalislo (1995) in another study. In *Litchi chinensis* placement of seeds vertically with their radicle downward results in better germination compared to sowing with radicle upward (Zhang et al., 2015). Sowing seeds of *Lagenaria siceraria* in a horizontal position resulted in better germination (Kelvin et al., 2015). In peanut seeds, the highest germination rate was recorded when seeds were sown vertically with hypocotyls end down, while the least germination was observed when the hypocotyls end was up (Ahn et al., 2016). This means that the appropriate position of seed placement during sowing is dependent on the type of species.

Though the effect of sowing orientation on germination of *Balanites aegyptiaca* was studied by Hall and Walker (1991), El Nour and Kalislo (1995), Sayda (2002), and Elfeel (2012), there seem to be contradictions in their findings. Therefore more studies are needed to establish the best sowing position that would lead to rapid and synchronized. The aim of this study therefore was to determine the optimum light requirement and the best sowing position of *Balanites aegyptiaca* seeds that would lead to rapid and synchronized germination which is an essential requirement for raising seedlings for plantation establishment and domestication programme.

METHODOLOGY

Study area

The study was carried out at the Seedlings Nursery of the Department of Forestry and Wildlife Management, Federal University Gashua, Yobe State, Nigeria. Gashua town is located between Latitude 12°51'.723"- 12°54'.723" N and longitude 11°00'.024" - 11°03'.475" E. The climate is divided into rain (June – September) and dry seasons (end of September – May). Average annual rainfall ranged between 500 to 1000 mm. The minimum temperature ranged from 23 to 28°C, while the maximum temperature ranges from 38 - to 40°C (Field Survey 2021).

Seeds collections

Ten (10) kg of mature fruits of *Balanites aegyptiaca* that are of good quality, free from pest or insect attack were collected from tree stands within the Federal University Gashua. The fruits were bulked and separated into different sizes; the larger fruits were selected for the experiment.

Experimental procedure

Selected fruits of *Balanites aegyptiaca* were de-pulped by soaking and washing in water to obtain the seeds. The viability of the seeds was tested using the floatation test (Wakawa and Akinyele 2016). 2,000 viable seeds were selected for the experiment. Seeds of *Balanites aegyptiaca* were randomly sampled from the bulk of viable seeds and sown at three different orientations (vertically with stalk upward (SO_1), vertically with stalk downward (SO_2), and horizontally (SO_3)) in germination trays filled with sterilized river sand. Light chambers were locally constructed with a wooden frame covered with 1 mm green mesh netting. Seeds sown in germination trays without a light chamber served as control (100% light intensity). Seeds sown in germination trays covered with one (1), two (2) and three (3) layers of green mesh nets represent 75% (L_2), 50% (L_3), and 25% (L_3) light penetration respectively (Akinyele, 2007). The germination trays were watered twice a day (morning and evening) while the experiment lasted. Germination count stopped after no new germination was observed for one (1) week. The experiment lasted for five weeks (35 days).

Experimental design

The experiment was arranged in a 4×3 factorial in a completely randomized design (CRD). The treatment combinations are shown in Table 1 below. Each treatment combination was made up of 12 germination trays, which translated to a total of 48 germination trays.

Table 1: Treatments Combination of 4×3 factorial

	Light intensity			
Seeds shape	L_1	L_2	L_3	L_4
SO_1	L_1SO_1	L_2SO_1	L_3SO_1	L_4SO_1
SO_2	L_lSO_2	L_2SO_2	L_3SO_2	L_4SO_2
SO_3	L_1SO_3	L_2SO_3	L_3SO_3	L_4SO_3

L_1:100% Light intensity, **L_2:**75% Light intensity, **L_3:**50% Light intensity, **L_4:**25% Light intensity, **SO_1:** Seeds sowed vertically with stalk upward, **SO_2:** Seeds sowed vertically with stalk downward, **SO_3:** Seeds sowed horizontally

Germination characteristics assessed

Germination percentage (GP)

Germination percentage was calculated based on the formulae adopted by International Seed Testing Association (ISTA) (1999) as shown below:

$$GP = \frac{Number\ of\ seeds\ germinatd}{Total\ number\ of\ seeds\ sown} \times 100$$

Mean germination time (MGT days)

Mean germination time (MGT) was determined according to Soltani et al, (2015) formulae given below:

MGT= $\sum(n.t)/\sum n$

t is the time from the beginning of the germination test in terms of days

n is the number of newly germinated seeds at Time *t*.

Germination speed (GS)

Germination speed (GS) was calculated using the equation of Maguire (1962), given as

$$GS = \frac{No.of\ germinated}{Days\ of\ first\ count} + - - + \frac{No.of\ seeds\ germinated}{days\ of\ final\ count}$$

Data analysis

Data collected were subjected to two ways Analysis of Variance (ANOVA) using STATISTICA Version 12. Mean separation where applicable was done using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Germination percentage

Light variation did not affect the germination percentage of *Balanites aegyptiaca* seeds significantly (Table 2). This implies that the germination of *Balanites aegyptiaca* seeds is not dependent on the amount of light exposed to. However, seeds exposed to 100% light intensity (control) had better performance (13.81±7.18%). According to Menegaes et al (2018), seed germination of some species is indifferent to light (neutral photoblastic), collaborating with our finding. In *Irvingia gabonensis* seeds, Onyekwelu et al. (2012) reported similar results when it was subjected to varying light exposure. A lack of significant difference in germination percentage of Moringa seeds exposed to light and darkness was also reported by Sakpere (2015). However, in other species, such as *Cassia fistula, Enterolobium saman, Delonix regia,* and *Chrysophyllum albidum*, exposure to different light significantly influenced germination. Seeds of different species respond differently under varying light intensity as observed by Menegaes et al (2018). Overall germination percentage recorded for all the light regimes was poor which we attributed to the dormancy effect of the seed as a result of the hard seed coat. We also suspect the low temperature observed during the experiment to have played a part in hindering germination. The study was conducted during the harmattan season when the temperature was low. Temperature is one of the environmental factors that can affect germination. The temperature in both extremes can decrease seed viability thereby reducing germination (Corbineau et al., 1986; Eberle et al., 2014).

Sowing orientation has no significant effect on the germination percentage of *Balanites aegyptiaca* seeds but seeds sown vertically with their stalk upward perform marginally better than other orientations (15.79±6.02%). Our result was contrary to that of Elfeel (2012) who reported sowing orientation to significantly affect the germination percentage of *Balanites aegyptiaca* seeds. According to Elfeel (2012) sowing *Balanites aegyptiaca* seeds in a vertical position with the stalk downward and horizontally gave better germination and differed significantly with seeds sown vertically with the stalk upward. Our result indicated that sowing seeds vertically with stalk upward gave better germination compared with those sown vertically with stalk downward and horizontally though the difference was not significant. The contradiction between our work and that of Elfeel (2012) is surprising since the species used are the same. Reports from other studies concerning the effect of sowing orientation on the germination percentage of *Balanites aegyptiaca* seeds such as that of Hall and Walker (1991) and Sayda (2002) all affirmed the superiority of sowing seeds vertically with stalk downward. However, El Nour and Kalislo (1995) reported poor germination when *Balanites aegyptiaca* seeds were sown vertically with stalk downward. This implies that there is an intra-specific variation in germination response among *Balanites aegyptiaca* seeds. Variation in germination response of seeds of different species when placed in a different position during sowing is common (Elfeel, 2012; Kelvin et al, 2015; Zhang et al, 2015) but variation among similar species is not common. Variation in seed characteristics among *Balanites aegyptiaca* species has been reported by Aviara et al. (2005). This could be one of the reasons responsible for the observed difference since the characteristics of seeds used in our study and that of Elfeel (2012) were not taken into consideration. Seed characteristics such as size, weight, etc affect germination (Egli and Rucker, 2012; Souza and Fagundes 2014; Tabakovic et al 2020).

Interaction between light intensity and sowing orientation did not significantly affect the germination percentage of *Balanites aegyptiaca* seeds. However, seeds exposed to 75% light and sown vertically with stalk upward gave a better germination percentage of 16.49±8.17 (Table 3). Sowing orientation seems to contribute more to this relationship than light intensity.

Mean germination time

The different light intensities had no significant effects on MGT, seeds sown under full light (control) took a longer period (15.50±2.87 days) before completing germination, while seeds exposed to 50% light intensity completed germination within the shortest possible time (11.99±6.36 days) (Table 2). Unlike in GP where exposure of *Balanites aegyptiaca* seeds to high light intensity resulted in higher GP, in MGT, low light intensity leads to early completion of germination. MGT is used to determine the number of days it takes for germination to start and conclude. The fewer the days spent to complete germination the better. Therefore exposing *Balanites aegyptiaca* seeds to 50% light intensity is better because it shortens the number of days required to complete germination. The number of days taken to complete germination in the seeds of some tropical forest species was reported to vary under different light conditions according to Borthwick (1957), this is similar to our observation though the variation was not significant.

Sowing seeds of *Balanites aegyptiaca* in different orientations did not affect MGT significantly. Seeds sown vertically with stalk upward require 15.17±2.84 days to complete germination, while seeds sown horizontally took fewer days (11.29±7.17) to complete germination. Our result is contrary to that of Kelvin et al. (2015) who reported MGT to vary significantly in seeds of *Lagenaria siceraria* when sown in a different position. This may be attributed to the difference in species and/or environmental factors from which the mother tree used for the collection of seeds was grown. The interaction between light intensity and sowing orientation on MGT was not significant, seeds sown vertically with stalk downward and exposed to 100% light intensity gave higher MGT (16.98±3.46 days), while those sown vertically with stalk downward and exposed to 75% light intensity had the least MGT of 7.83±13.57 days. This implies that sowing *Balanites aegyptiaca* seed vertically with the stalk downward and exposed to 75% light intensity will reduce the time taken to complete germination.

Germination speed

The germination speed of *Balanites aegyptiaca* was not affected by exposure to different light intensities. Seeds sown under 100% light intensity germinated faster (2.85±1.84) in comparison with other light treatments (Table 2). Seeds exposed to 75% light intensity had the slowest germination speed (1.95±1.90). This means sowing *Balanites aegyptiaca* seeds in high light intensity could lead to rapid germination. Rapidity during seed germination is very important. Seeds that germinate faster and in large numbers during germination are generally preferred because it is an indication of a favourable germination condition

(Sarvas, 1950). Contrary to our result, the germination rate in the seeds of four tropical species was found to vary significantly (Borthwick 1957). Since the species are different, we assumed individual species difference was responsible for variation in behaviour.

Sowing orientation significantly affects the germination speed of *Balanites aegyptiaca* seeds. Seeds sown vertically with stalk upward germinate faster (3.44±1.85) and differed significantly from those sown vertically with stalk downward which had 1.13±1.18. Our result agreed with that of Kelvin et al (2015) who reported a significant difference in GS of *Lagenaria siceraria* sown in a different orientation. Ahn et al. (2017) also reported that sowing orientation significantly affects the GS of peanut seeds. The interaction between light intensity and sowing orientation was not significant. Seeds sown vertically with stalk upward and exposed to 25% light intensity had a faster germination rate (3.99±3.06S2), while those sown vertically with stalk downward and exposed to 75% light intensity had the lowest germination speed (0.47±0.81)

Table 2: Effects of light intensity and sowing orientation on germination characteristics of *Balanites aegyptiaca*

Treatments	GP	MGT (days)	GS
L1	13.81±7.18	15.50±2.87	2.85±1.84
L2	10.52±9.67	10.96±9.10	1.95±1.90
L3	11.27±7.54	11.99±6.36	2.46±1.83
L4	12.54±11.06	12.11±8.52	2.70±2.65
S1	15.79±6.02	15.17±2.84	3.44 ± 1.85^{a}
S2	7.03±7.25	11.46±9.39	1.13 ± 1.18^{b}
S3	13.29±10.38	11.29±7.17	2.90 ± 2.24^{ab}

Note: Mean carrying the same alphabet did not vary significantly $p \leq 0.05$. Means values are followed by standard deviation. L1=100% Light Intensity, L2=75% Light Intensity, L3=50% Light Intensity, L4=25% Light Intensity, S1= Seed sown vertically with stalk upward, S2= Seed sown vertically with stalk downward, S3= Seed sown horizontally

Table 3: Effect of interaction between light intensity and sowing orientation on germination characteristics of *Balanites aegyptiaca*

Treatments		GP	MGT	GS
L1	S1	15.24±3.59	15.22±2.45	3.14±1.30
L1	S2	10.48±7.87	16.98±3.46	1.90±1.61
L1	S3	15.71±10.30	14.31±3.09	3.51±2.67
L2	S1	16.49±8.17	15.17±4.80	3.17±1.93
L2	S2	3.81±6.60	7.83±13.57	0.47±0.81
L2	S3	11.25±11.91	9.89±9.02	2.20±2.12
L3	S1	15.71±6.22	14.78±3.75	3.46±1.82
L3	S2	7.15±6.55	11.97±7.76	1.26±1.01
L3	S3	10.95±9.51	9.22±8.01	2.67±2.32
L4	S1	15.72±8.92	15.52±0.90	3.99±3.06
L4	S2	6.67±10.33	9.07±12.40	0.89±1.34
L4	S3	15.24±15.00	11.73±10.20	3.22±3.02

Note: Mean carrying the same alphabet did not vary significantly $p \leq 0.05$. Means values are followed by standard deviation.

L1=100% Light Intensity, L2=75% Light Intensity, L3=50% Light Intensity, L4=25% Light Intensity, S1= Seed sown vertically with stalk upward, S2= Seed sown vertically with stalk downward, S3= Seed sown horizontally, L×S= Interaction between light intensity and sowing orientation

CONCLUSION

Germination characteristics of *Balanites aegyptiaca* seeds were not affected by the intensity of light. This is an indication of the ability of the seeds to germinate irrespective of the intensity of light. Sowing *Balanites aegyptiaca* seeds vertically with the stalk upward gave better germination characteristics even though the difference from other sowing orientations was not significant. Sowing of *Balanites aegyptiaca* seeds in a vertical position with their stalk upward under moderate light exposure is therefore recommended.

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