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Muzafar Kanaby Omar

muzafar.kanaby@koyauniversity.org

Salahaddin University- Erbil

Abdulbaset Mohammed Amin Mohammed

Salahaddin University- Erbil

Nawzad Bawakir Kadir

Salahaddin University- Erbil

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Impact of Acorn Moth (*Cydia fagiglandana*) Infestation on Seedling Vigor and Early Recovery of Persian Oak (*Quercus brantii*) in Koya District

Muzafar Kanaby Omar^{1,3}, Abdulbaset Mohammed Amin Mohammed¹ and Nawzad Bawakir Kadir²

¹ Forestry Department, College of Agricultural Engineering Sciences, Salahaddin University- Erbil, Erbil, Kurdistan, Iraq

² Plant Protection Department, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Erbil, Kurdistan, Iraq

³ Department of Biology, Faculty of Science and Health, Koya University, Koya 44023, Kurdistan Region – F.R. Iraq

Corresponding author: Muzafar Kanaby Omar (E-Mail:

muzafar.kanaby@koyauniversity.org, ORCID: <https://orcid.org/0000-0002-6604-313X>)

Abstract

This study is a detailed field assessment the effect of Acorn Moth (*Cydia fagiglandana*) on the growth ability and early stages of recovery of Persian Oak (*Quercus brantii*) in different areas of Koya district (Aliawa, Wnka, Kanibi, Qurtalas, Jaly and Chnarok) in (2024 and 2025). For this purpose, a total of 1440 seedlings (divided in equal proportions between healthy and *C. fagiglandana* larvae infested seedlings from 240 different trees) were collected and planted in a protected environment in Haibat Sultan plain without using any fertilizer or unhealthy artificial irrigation. Statistical results using hierarchical analysis (ANOVA) and Duncan's Test showed that seed health has a decisive effect on the success of the greening process. Healthy seedlings showed high physiological potential and recorded root output rate ranging from 87.39% to 90.93% and stem formation rate ranging from 82.08% to 86.14%; While the infested plants, due to the Acorn Moth larvae eating the tissue and nutrients in their seed, the root emergence rate dropped to about 59.89%-63.64% and the stem formation rate dropped to a dangerous level ranging from 23.95%-27.60%. Geographical differences also played a role, with Kanibi forest recording the highest growth rate, while Chnarok forest recorded the lowest. This study shows

that persistent *C. fagiglandana* invasion is a chronic and formidable obstacle to natural forest regeneration, causing generation chain breaks and irreplaceable drying of old trees, which requires urgent planning for sustainable forest conservation and management.

Keywords: Persian Oak (*Quercus brantii*), Acorn Moth (*Cydia fagiglandana*), Oak Seed Predation, Natural Regeneration, Forest Degradation

1. Introduction

Natural forests in the Iraqi Kurdistan Region, especially those covered with trees, are considered one of the most important natural and plant resources in the region that play a fundamental role in maintaining environmental balance, mitigating the impacts of climate change and providing biodiversity (Radha and Khwarahm 2022, Ghaedi, et al. 2026, Psistaki, et al. 2024). Among the major forest types, Brant Oak or Persian Oak (*Quercus brantii* Lindl.) appears as a major woody element in mountainous and hillside areas and forms the main basis of forest ecosystems (Wang, et al. 2025, Safari, et al. 2022, Mirhashemi, et al. 2023).

However, in recent years, the forests in the Kurdistan Region, especially in the areas of Erbil province and Koya district, have faced a number of serious threats and rapid degradation that poses a serious threat to their future survival (Iordache, et al. 2026, Salehi, et al. 2013). The nature of the forests in these areas appears to be patchy and open, in which the trees are scattered in long and close proportions (Manning, et al. 2006). The causes of this environmental decline are manifold and include: continuous neglect, human encroachment and improper activities of villagers and tourists in different seasons, with rapid spread of diseases and severe attacks of drilling insects and parasites on deciduous trees (Panzavolta, et al. 2021).

One of the most dangerous biological factors that deals a deadly blow to forest natural regeneration is the Acorn Moth (*Cydia fagiglandana* Zeller) (Ferracini, et al. 2021) commonly known as the beech mast piercer or large beech piercer, is a species of micro-moth belonging to the family Tortricidae and Lepidoptera order. It is widespread across Europe and extends into Central Asia and Northern Iran (Ferracini, et al. 2021). This insect is distinguished by its larvae attacking and eating the ripe fruit, so that in some areas the damage rate exceeds three-quarters (75%) of the total annual fruit production (Hashimi, et al. 2024). This extensive damage causes the destruction of large amounts of seed banks and the loss of the ability to clean and grow

natural trees, so that natural germination in the areas is very short (Mei, et al. 2025). According to scientific predictions and field data, if the insect continues, the forests of these areas will face complete extinction in the near future, because there are no new trees to replace the old trees (Hacket-Pain and Bogdziewicz 2021).

Scientific Objective: The main objective of this study is to conduct a detailed laboratory and field assessment of the actual effects of fruit parasite *Cydia fagiglandana* on reduced viability, early recovery, and root and stem emergence rates of *Quercus brantii*, in order to achieve the following secondary environmental objectives:

Determine the exact rate of disruption of the initial growth process (root and stem emergence) between healthy and damaged faces in a protected environment.

Therefore, this study aims to determine the true effect of *C. fagiglandana* insect damage on initial tree regeneration capacity (root and stem emergence rate) by comparing healthy and damaged trees in a protected environment, in order to provide scientific data for forest conservation and regeneration strategies.

Estimating the magnitude of biological threats to the interruption of new generation chains and weakening of the natural sustainability of Zagros forests in Koya district.

Provide scientific data and basic principles for developing effective strategies for the conservation, rehabilitation and sustainable management of forests with the aim of preventing the extinction of common trees in the future.

2. Materials and Methods

2.1. Study Area

This study was conducted during two years in October 2024 and 2025 in natural forests of several villages belonging to Koya district in Erbil province, Iraqi Kurdistan Region. Sample collection areas included: Aliawa, Wnka, Kanibi, Qurtalas, Jaly and Chnarok.

2.2. Sample Collection

In total, 1440 fruits of *Quercus brantii* were collected in these areas. A total of 240 trees were collected from each area, divided into two categories: 120 Faces damaged by insect larvae *Cydia fagiglandana* and 120 Healthy faces (Timm, et al. 2025). Samples were scientifically collected from 4 deciduous trees in the natural forests of each area (an average of 60 trees per tree, equivalent to 30 damaged and 30 healthy trees per tree), to ensure genetic and environmental diversity of the samples (Haq, et al. 2023,Stamin and Cosmulescu 2025). To ensure the accuracy of the results, damaged and healthy plants were taken from the same tree and possessed the same size, species, and structure, differing only in the presence or absence of the infection (Olanrewaju, et al. 2024).

2.3. Morphometric Measurements and Ecological Protection of Samples

2.3.1. Weight and Size Measurement (Morphometric Analysis)

Before the planting process, detailed morphological measurements were taken for each of the collected fruits (both in the healthy fruit category and in the *Cydia fagiglandana* damaged fruit category). The total weight of each plant was recorded separately via a high-precision Sensitive Electronic Balance (in grams). This scientific step was followed to ensure equality or difference in size and basic weight between samples, so that no effect of size on growth rate and recovery was controlled with same size and the data obtained truly reflected the damage effect of the insect.

2.3.2. Planting Systems and Natural Growth Conditions

To preserve the natural aspect and authenticity of the plant revival process away from any artificial modification, the planting process relied entirely on natural rainfall. No artificial irrigation or fertilizers were used in order to keep the plantation environment in its natural world state, so that the evidence and results are fully realistic and reflect the natural tolerance of the species.

2.3.3. Exclosure and Protection Measures

Torin boxes and wire mesh exclosure cages were used to protect the planted samples from any external threats that could damage or eat the plants by wild animals, insects, or any other environmental pest. These mesh boxes were positioned solidly over the planting site, which

simultaneously allowed the passage of light, air, and amount of rainwater, providing seedlings with a protected and controlled environment to undergo the initial stage of root and stem emergence without any external barriers.

2.4. Planting and Monitoring Methods

After sampling in October of both years, the plants were quickly transported to the laboratory and destination. In the same month, seedlings (both damaged and healthy species) were naturally transplanted into the soil in the Haibat Sultan Forest on the mountainside, in a protected area belonging to Koya University (near the Faculty of Science and Health). To bring the environment closer to its natural state, in addition to natural sand, a layer of deciduous leaves and dry herbs of appropriate thickness was placed on the boxes. Regarding irrigation, in both years rainwater was initially relied upon; Meanwhile, to maintain balance and control the differences in climate (wet and dry) between the two years, manual irrigation was used scientifically to equalize the moisture content of the plantation environment. The process of monitoring and measuring growth was conducted in the following stages:

Stage 1 (root emergence): After two months of planting (in December), the plants (damaged and healthy) were excavated or examined to record the rate of root formation, which is considered the earliest part of plant survival and growth.

Stage 2 (stem emergence): Two month after the first stage (in late January and early February of next year), the plants were continuously monitored and the rate of stem formation was recorded by counting the number of green plants that had emerged (Rijkers et al., 2000).

2.5. Monitoring and Data Collection

After three months of monitoring and servicing the plants, the proportion of plants that were able to root was recorded (distinguishing between healthy and damaged plants). Then, after another two months (corresponding to five months from the start of planting), the proportion of specimens that were able to form stems was recorded (Weksler, et al. 2021,Kamanga, et al. 2026).

2.6. Statistical Analysis

To evaluate the data obtained and determine the effect of differences between classes, all recorded data on root and stem emergence rates were subjected to detailed statistical analysis. In this study, Analysis of Variance (ANOVA) was used to examine the existence of Significant Differences between the average data of different areas and type of samples (intact vs. damaged surface).

Also, Duncan's Multiple Range Test (Duncan Group) was used to compare the means between different groups and to determine the level of statistically significant differences in data rates. All statistical analyzes were performed at the confidence level (0.05), and results were presented as mean and standard deviation to explain differences among regions and the impact of insect damage.

3. Results

In this study, the effect of Acorn Moth (*Cydia fagiglandana*) on the growth ability and speed of initiation of recovery stages of Brant Oak (*Quercus brantii*) in different areas of Koya district (Aliawa, Wnka, Kanibi, Qurtalas, Jaly and Chnarok) was discussed. Based on morphometric measurements and statistical analyzes (ANOVA and Duncan experiment).

3.1. Effect of damage on root emergence

Experimental and field tests conducted two months after planting (in December) showed that the presence of insect damage had a direct and significant negative impact on the initial ability of the seeds to germinate:

Healthy seeds: They recorded a high success rate in root emergence, which showed the strong growth nature of the tree under normal conditions.

Damaged seeds (*Cydia fagiglandana*): showed a significant and dangerous decrease in root emergence ability, in such a way that the nutrient energy in the blue kernel was reduced due to the attack of the insect larvae, which caused significant delay and disruption of the initial rooting process (Liu, et al. 2024).

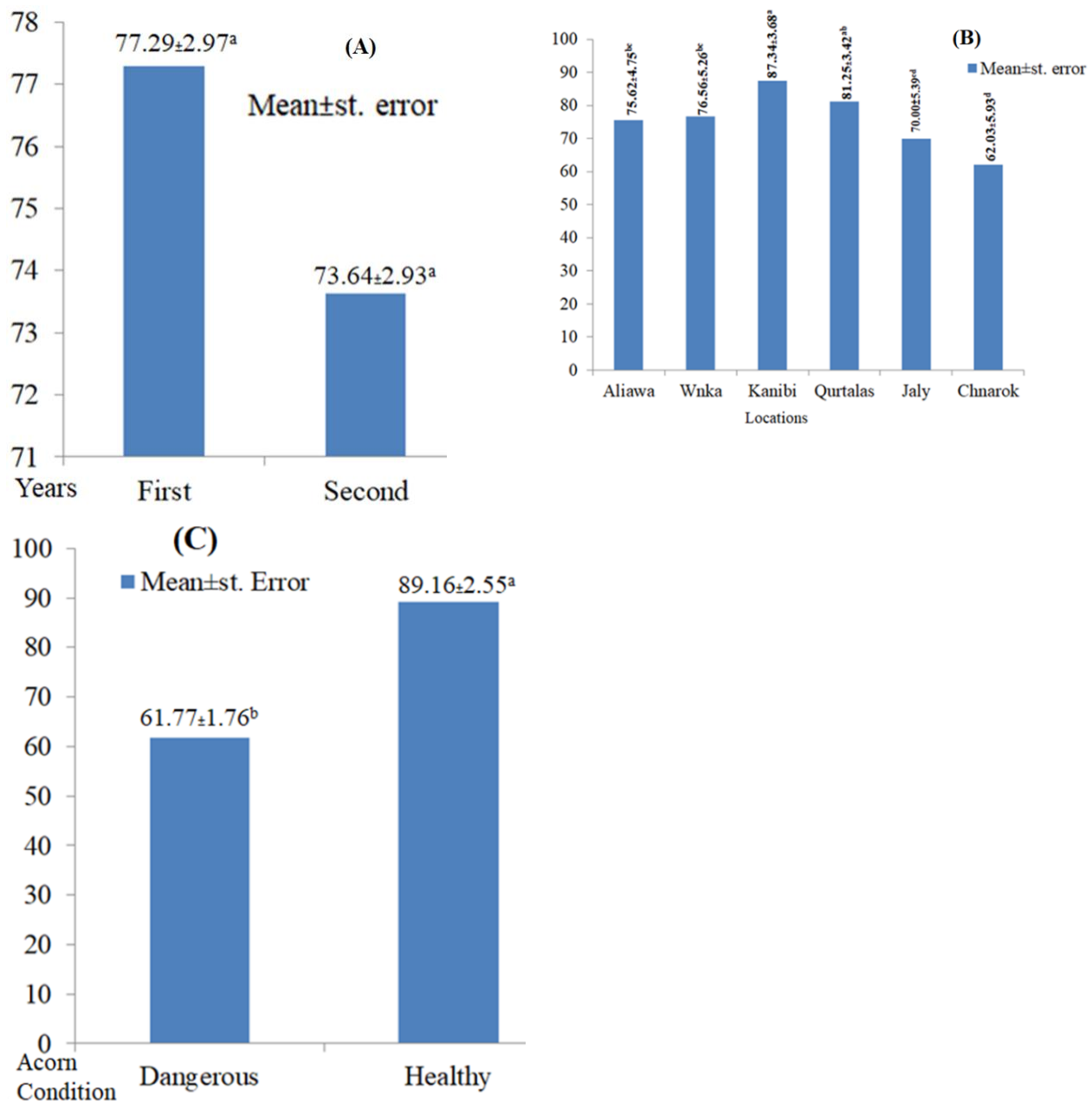


Figure (1): Chart (A): Effect of insect damage (*Cydia fagiglandana*) on root emergence rate of *Quercus brantii* acorns, (B): Effect of different years on root emergence rate of *Q. brantii* acorns, (C): Effect of different regions on the rate of root extraction in *Q. brantii* acorns.

In Figure (1), charts present the results of a scientific study on the rate of root production by *Quercus brantii*, (A): explains the difference between healthy and *C. fagiglandana*-infested roots. (B): The rate of root production by *Q. brantii* during two different years. Chart (C)

presents the results of a scientific study on the rate of root production by *Q. brantii* in six different regions. Healthy acorns recorded the highest root emergence rate with mean and standard error of (89.16 ± 2.55) , and is indicated by letter (a) indicating significant statistical difference. Acorns damaged by *C. fagiglandana* had a decreased root emergence rate to the mean and standard error or (61.77 ± 1.76) , and is indicated by letter (b). The chart clearly shows that insect damage has a significant negative impact on the ability of fruits to grow and root, with healthy fruits having much greater ability than damaged acorns to root.

In the first year, the root removal rate recorded the highest level with a mean and standard error of (77.29 ± 2.97) , and is indicated by the letter (a). In the second year, the root removal rate decreased slightly to the mean and standard error or (73.64 ± 2.93) , and this is also denoted by the letter (a). The use of the same letter (a) for both years indicates that there was no significant difference between the first and second years in the root emergence process, indicating that the effect of years on the root emergence rate was close to the same.

According to locations, Kanibi was recorded the highest root removal rate is with mean and standard error of (87.34 ± 3.68) , and is indicated by letter (a). Qurtalas region was recorded the second highest rate with mean and standard error or (81.25 ± 3.42) , and is denoted by a combination of letters (ab). The root removal rate in Wnka area was (76.56 ± 5.26) , and is indicated by the letters (bc). The root removal rate about of Aliawa this area was (75.62 ± 4.75) , and is also denoted by the letters (bc). Jaly area was decreased to (70.00 ± 5.39) of the root emission rate in this area, and is indicated by the letters (cd). Also the lowest root expulsion rate was recorded in Chnarok area was (62.03 ± 5.93) , and is marked with the letter (d). The differences in letters (a, ab, bc, cd, d) indicate significant statistical differences between some regions in the root extraction process, indicating that geography and environmental characteristics of different regions affected the growth ability of plants.

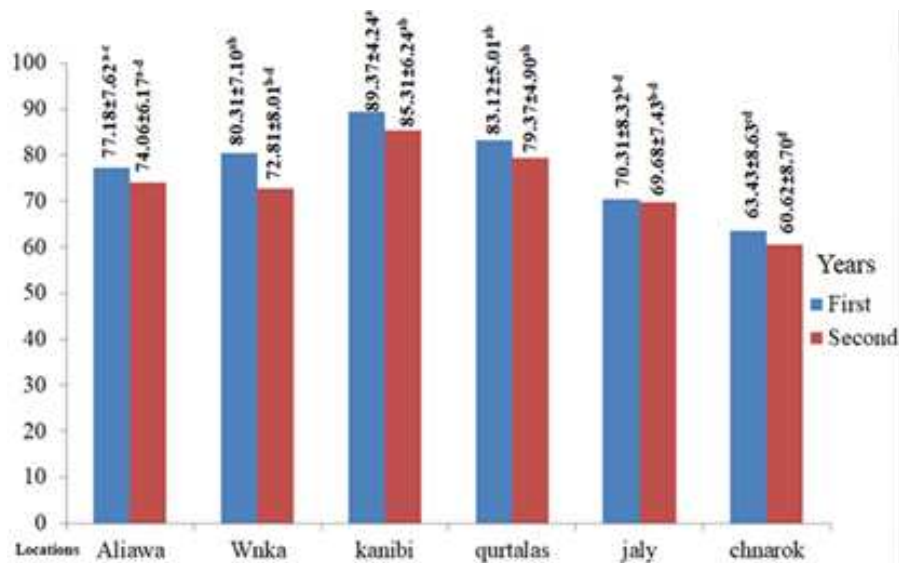


Figure (2): Effect of different geographical areas and collection years on root product rate of *Quercus brantii* acorns.

This clustered column chart in figure (2) presents the results of a scientific experiment in which the root extraction rate of *Q. brantii* in six different geographical areas was compared during two different years (year 1 - blue column, and year 2 - red column).

In Aliawa location, for first year (blue) was (77.18±7.62), and was indicated by the letters (a-c) and was (74.06±6.17), and is indicated by the letters (a-d) for second year (red). During first year was (80.31±7.10), and was indicated by the letters (ab) in Wnka region and next year was (72.81±8.01), and was indicated by the letters (b-d). In Kanibi location the highest overall rate across the chart was recorded in year 1 was (89.37±4.24), marked with letter (a), and in second year also records the highest rate was (85.31±6.24), and was denoted by the letters (ab). Qurtalas Region was (83.12±5.01), and is indicated by the letters (ab) for first year, as well as second year was (79.37±4.90), and was denoted by the letters (ab). Mean and standard error is (70.31±8.32), and was indicated by letters (b-d) in Jaly Area in year (1) but for year (2) was (69.68±7.43), marked with letter (b-d). The lowest first year rate is recorded for Chnarok area in first year was (63.43±8.63), and was indicated by the letters (cd), also the lowest overall rate across the chart is recorded in this area during second year was (60.62±8.70), and was indicated by the letter (d).

The chart shows that geographical areas have a significant impact on the ability of plants to root; in a sense, Kanibi region recorded the highest and Chnarok region the lowest. Also, across all regions, the rate of root removal in the first year was generally slightly higher than in the second year.

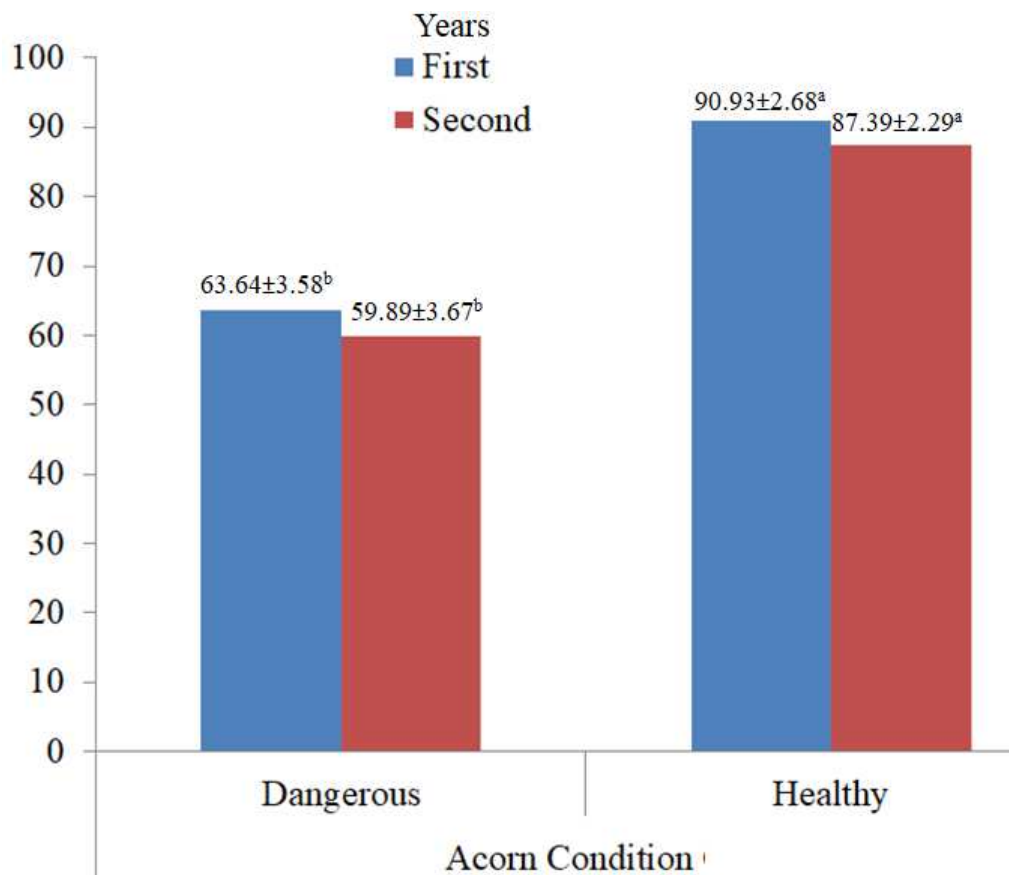


Figure (3): Effect of *C. fagiglandana* infestation on the percentage of root extraction of *Q. brantii* during two years of study.

In figure (3) the chart explains the percentage of root removal from *Quercus brantii* fruit according to health status (healthy vs. infected) for two consecutive years. The percentage of root extraction in healthy fruits reached the highest level with (90.93±2.68) marked with letter (a) in the first year while in infected acorns (Dangerous) the percentage decreased to (63.64±3.58) with category (b).

The second year percentage of root product in healthy fruits was (87.39 ± 2.29) with letter (a), while in infected acorns decreased to (59.89 ± 3.67) with letter (b). The presence of different letters (a and b) indicates a significant difference between the two groups. This proves that the infestation of *Quercus brantii* with *Cydia fagiglandana* had a negative and severe effect on the primary growth potential and nectar ejection of the fruits in both the years studied.

These data resolve an important debate about seed quality and natural vegetation degradation in oak forests. Frequently in the natural environment, large numbers of bark of *Quercus brantii* trees are infested by the insect *Cydia fagiglandana*. This study proved that despite some damaged seedlings still being able to root during the first and second periods (about 60%), their growth potential would be weaker by about 27-30% compared to clean, healthy seedlings. This will have a major negative impact on the success of forest and nature revitalization projects and the natural survival of this valuable tree species. As supported by broader ecological literature on forest pests (Moreno, et al. 2013, Hébert 2023), seed predation by Tortricid moths acts as a critical bottleneck for natural regeneration, depleting crucial cotyledon reserves necessary for early establishment under competitive forest canopy conditions.

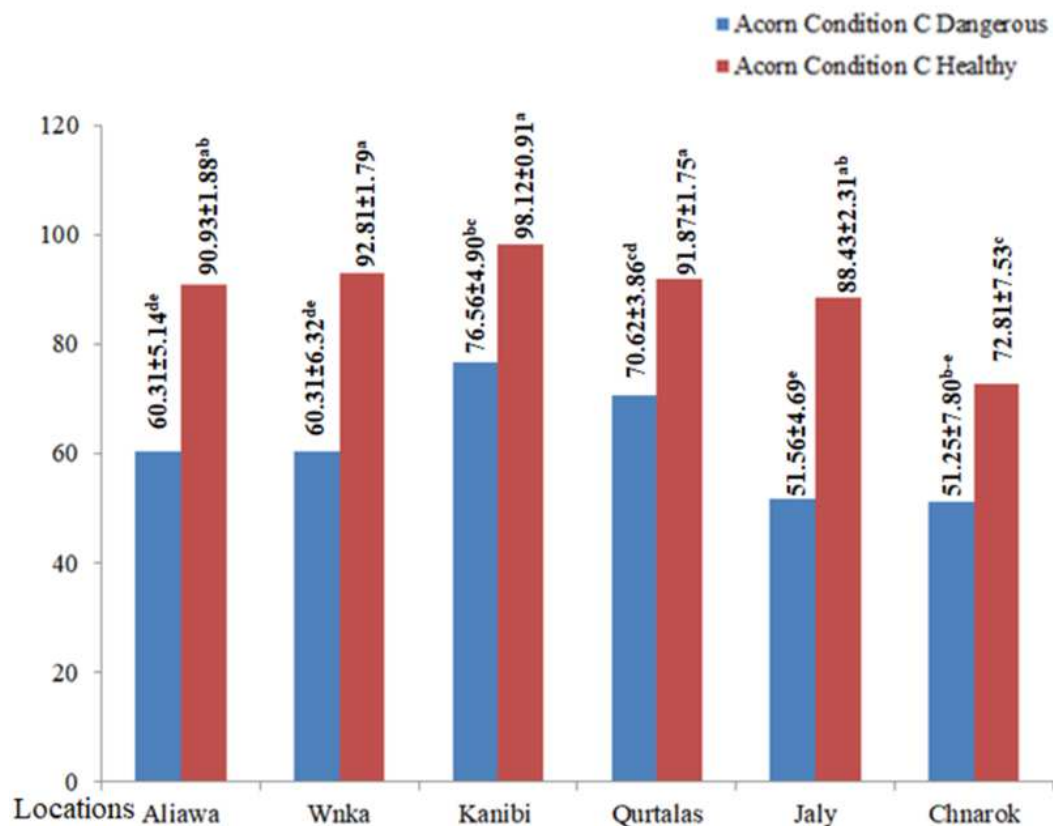


Figure (4): Effect of combination of geographical areas and plant health status (healthy vs. damaged by *Cydia fagiglandana* larvae) on the rate of root emergence in plant species *Quercus brantii* acorns.

The results of extensive scientific analysis in figure (4) that presented as chart form was combined effect of both geographical area and health status of *Quercus brantii* on root emergence rate. The chart divides the data for six different areas (Aliawa, Wnka, Kanibi, Qurtalas, Jaly, Chnarok) into two statuses: damaged or dangerous acorns (Dangerous - blue column) and healthy acorns (Healthy - red column).

Damaged acorns (blue) was (60.31±5.14) in Aliawa area and is indicated by the letters (de). Healthy acorns (red) of the same area (90.93±1.88), and is denoted by the letters (ab). In Wnka region was recorded (60.31±6.32) for dangerous acorn, was indicated by the letters (de). Also healthy was recorded the highest rate in this region as (92.81±1.79) and was denoted by the letter (a). Kanibi location was recorded the highest root product rate for damaged face was (76.56±4.90), and was indicated by the letters (bc) and the healthy (red) was the highest overall

rate across the chart was recorded of (98.12 ± 0.91) , and with category (a). Damaged face (blue) in Qurtalas Region was (70.62 ± 3.86) , and marked with letter (cd) and healthy fruits (red) (91.87 ± 1.75) , and marked with letter (a). Jaly area was (51.56 ± 4.69) , and was indicated by the letter (e) for dangerous acorn and was (88.43 ± 2.31) , with category (ab) for healthy face (red). In Chnarok location, the lowest overall rate of root emerging in this category was recorded with (51.25 ± 7.80) for damaged face (blue), and was indicated by the letters (be), and healthy face (red) was (72.81 ± 7.53) , with category (c).

The chart clearly shows a very large difference between the ability to root healthy and damaged plants; In all areas, healthy stands (red columns) had significantly higher rates of root ejection than damaged stands (blue columns). Statistical letters (a, b, c, d, e) explain statistical differences and similarities between groups, where the presence of common letters indicates no strong difference, while different letters have shown significant statistical differences.

This table shows that not only the health of the fruit (freedom from insects), but also the geographical location of the region plays a role in the quality of the plants. For example, Kanibi area had the best environment as it recorded the highest rate of rooting both for healthy (98.12%) and damaged (76.56%) stands. In contrast, the poplar zone had the lowest rooting potential in both cases, settling an important scientific question on the influence of local environmental factors and insect (*Cydia fagiglandana*) stress on the nature of different forest zones as mentioned by (Albajes, et al. 2026, Soler, et al. 2008). These spatial discrepancies align with regional variations in microclimate, soil physicochemical properties, and maternal tree vigor documented in forest ecology studies (Lindman, et al. 2023, Zu, et al. 2022), demonstrating that local habitat quality can modulate the baseline resilience of oak seeds against biotic stressors.

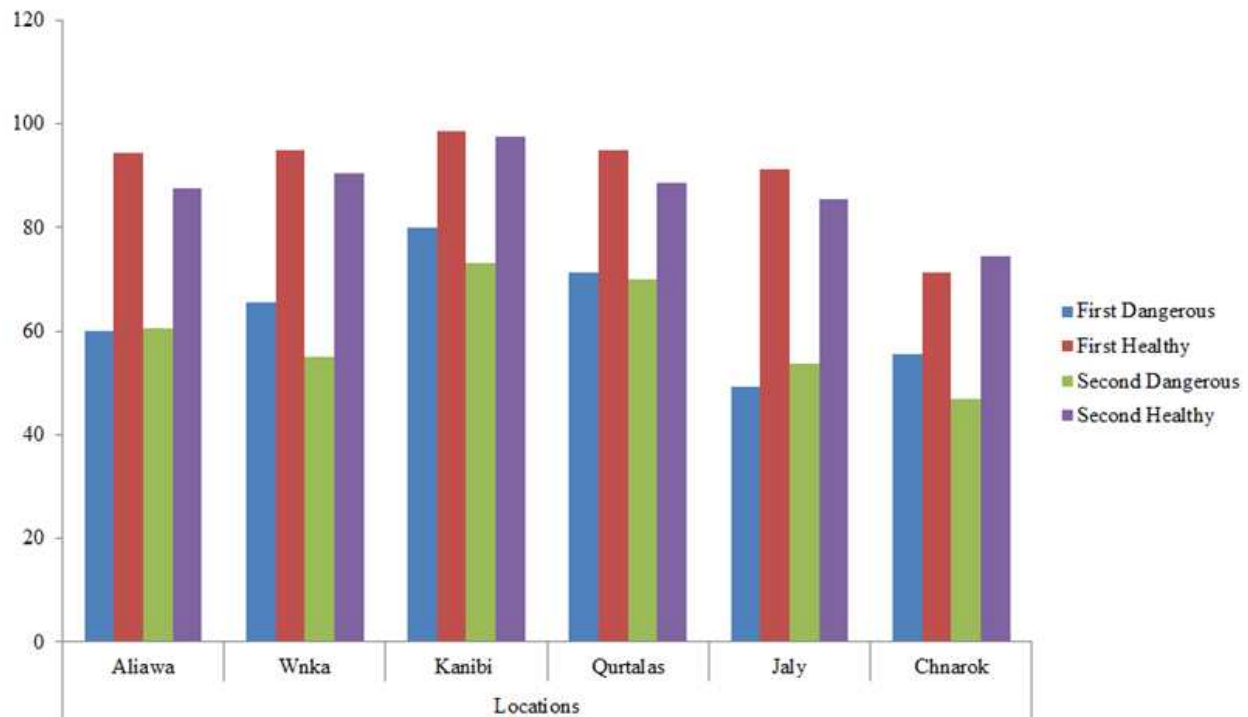


Figure (5): Effect of *Cydia fagiglandana* insect damage on the percentage of pollen extrusion in *Quercus brantii* acorns in six different areas for two consecutive years

The Figure (5) show the root emergence percentage of *Quercus brantii*, which were collected and planted in two cases (healthy and damaged by *Cydia fagiglandana*) during two different years in six different areas (Aliawa, Wnka, Kanibi, Qurtalas, Jaly, Chnarok).

In First Year, Kanibi location was recorded the highest success rate; Healthy surface reached (98.75 ± 1.25) which has the highest category (a), and damaged surface had the highest percentage of all areas with (80.00 ± 4.89) in category (a-g). But Qurtalas region was (95.00 ± 2.28) for Healthy faces with category (a-c), and damaged acorns was (71.25 ± 4.27) with category (d-i), and in Wnka area, healthy faces recorded (95.00 ± 2.04) was indicated by the letter (a-c), while damaged faces (65.62 ± 9.37) was denoted by the letter (f-j). In Aliawa location, healthy face reached (94.37 ± 1.19) with category (a-d), and damaged face (60.00 ± 8.53) with letter (g-j). Then healthy faces in Jaly area was (91.25 ± 2.97) and was indicated by the letter (a-e), and damaged faces had (49.37 ± 4.71) with category (ij). Also in Chnarok location, was recorded the lowest level in the first year; it was to healthy (71.25 ± 12.09) was denoted by the letter (d-i) and (55.62 ± 12.68) for damaged acorns and (h-j) was as indicated letter.

Kanibi location was leading in the second year; It reached a maximum of (97.50 ± 1.44) on the healthy fruits with category (ab), and on the damaged surface it was (73.12 ± 8.97) was denoted by the letter (c-h). In locations of Wnka, Qurtalas, Aliawa and Jaly, healthy fruits recorded (90.62 ± 2.77) , (88.75 ± 1.61) , (87.50 ± 2.70) and (85.62 ± 3.28) were denoted by the letter (a-e), (a-e), (a-f) and (a-f), while damaged face were (55.00 ± 8.95) , (70.00 ± 7.14) , (60.62 ± 7.09) and (53.75 ± 8.80) with categories (h-j), (e-i), (g-j) and (h-j) respectively. But Chnarok was recorded the lowest overall result during second year for healthy fruit (74.37 ± 10.81) with category (b-h) and for damaged fruit brought the lowest percentage of all the regions was (46.87 ± 10.52) was denoted by the letter (j).

Overall, fruits health condition in all regions and in both years, the rate of root emerge were significantly and statistically higher than that from fruit damaged condition by *Cydia fagiglandana*. This clearly shows the negative and devastating effect of this insect attack on the growth potential and viability of *Quercus brantii*. Healthy acorns always have higher success rates (often ranging from above 85% to about 98.75%), while damaged fruits drop significantly to below 50% in some places such as Chnarok and Jaly (46.87^j and 49.37^h (Castro-Alija, et al. ,Petros, et al. 2026)). This shows that the attack of this insect and damage to the inside or tissues of the acorns gives a serious blow to the ability to root.

The Kanibi area consistently recorded the highest and best results in both years (especially with healthy surfaces of 98.75 ± 1.25^a), indicating the suitability of environmental conditions or basic tree health in that area. In contrast, Chnarok and Jaly areas had the lowest levels of root expulsion, with Chnarok averaging the lowest (46.87 ± 10.52^j) for damaged surfaces in the second year), which may be related to differences in soil microstructure, air, or insect infestation severity.

The effect of year (first year vs. second year) shows some slight changes, for example in Chnarok area the healthy side was (71.25) in the first year and increased to (74.37) in the second year, while in Wnka the damaged side was (65.62) in the first year. This annual difference could be attributed to climatic changes or differences in the intensity of the insect curl during the two years during collection and planting.

This complex statistical analysis presents a decisive scientific fact: despite the differences in regions and years, the factor of fruit health (freedom from insects) is a greater and more dominant force on the ability of root growth to succeed (Puig-Gironès, et al. 2023, Fang, et al. 2025). So, insect attack (*Cydia fagiglandana*) disturbs the natural balance of forest regeneration, and when planning for *Quercus brantii* conservation and replanting, clean-faced collection must be mainly relied upon in good areas with letters closer to group (a) (Mihai, et al. 2022). These discussion reinforce modern restoration paradigms emphasizing seed lot selection based on phytosanitary quality rather than geographical convenience alone (Whyte, et al. 2016, Mezquida, et al. 2021).

3.2. Effect on Stem Emergence

In the second phase of inspections (conducted five months after the start of planting in the Haybat Sultan Mountain Protected Area), the differences became more apparent:

Statistical analysis proved that the success rate of stem and leaf bluing between different areas such as (Aliawa, Wanka, Kanibi, Qurtales, Jeli and Chenarok) had statistical differences, so that the areas with higher infection rates suffered more severe damage.

Experimental results confirmed that the insect's damage has interrupted the chain of new generations of blue trees and dangerously weakened the natural ability of forests to renew and resist climate change, as the ability of seeds to turn completely blue in the damaged debris has been significantly reduced.

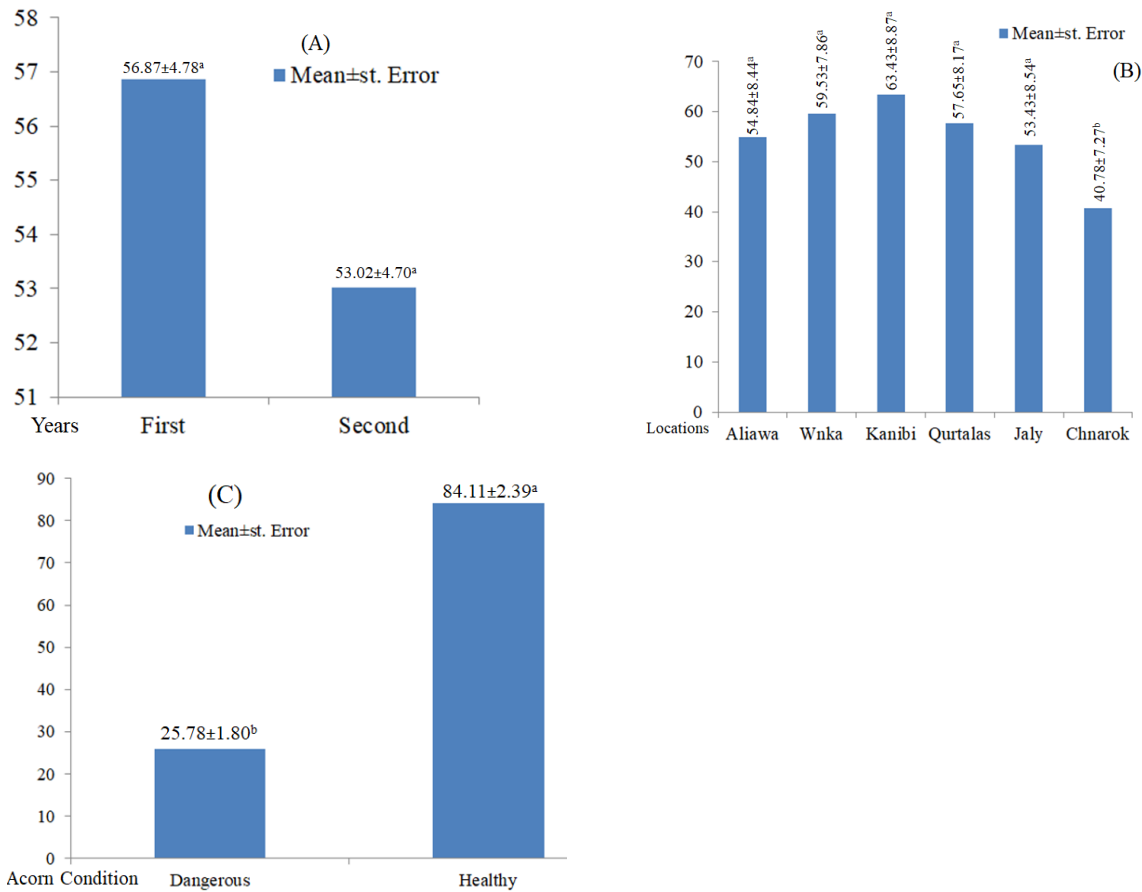


Figure (6): Chart (A): Effect of different years on stem formation rate by *Quercus brantii* acorns, (B): Effect of six different geographical areas on the rate of stem formation by acorns of *Quercus brantii*, (C): Effect of *Quercus brantii* - healthy vs. *Cydia fagiglandana* larva-damaged fruit condition on stem formation rate.

This column chart (A) in figure (6) presents the results of a scientific study that compared the rate of stem formation by *Quercus brantii* over two different years. The stem construction rate recorded the highest level first year was 56.87 ± 4.78 and was marked with the letter (a). In second year the stem formation rate has decreased slightly for (53.02 ± 4.70), was denoted by the same letter (a). Overall, the rate of stem formation was slightly higher in the first year than in the second year but use the same statistical letter (a) for both years indicates that there is no statistically significant.

This column chart (B) in figure (5) presents the results of a scientific study that compared the rate of stem formation by *Quercus brantii* in six different geographical areas. In Aliawa area the

stem formation rate was (54.84 ± 8.44) , was marked with the letter (a). The mean and standard error in Wnka region was (59.53 ± 7.86) , and denoted by the same letter (a). The highest stem formation rate across was recorded Kanibi locaion (63.43 ± 8.87) , was marked with the letter (a). Also in Qurtalas and Jaly region were (57.65 ± 8.17) and (53.43 ± 8.54) respectively, was marked with the same letter (a). The lowest stem formation rate was recorded in Chnarok area was (40.78 ± 7.27) , and was marked with the letter (b). At results, that shows in chart, Kanibi region recorded the highest and Chnarok region the lowest level of stem production. In contrast, the use of the letter (b) for the Chnarok area indicates that this area has a significant statistical difference compared to other areas in the construction process. The use of the same statistical letter (a) for the first five regions (Aliawa, Wnka, Kanibi, Qurtalas, Jaly) indicates that there is no significant statistical difference between these regions.

This column chart (C) in figure (5) presents the results of a scientific study in which the rate of stem formation by the roots of *Quercus brantii* according to the status of the fruit (Dangerous, and Healthy). Dangerous fruits, stem formation rate were the lowest was (25.78 ± 1.80) , and was marked with the letter (b). The stem formation rate in healthy was the highest level was (84.11 ± 2.39) , was marked with the letter (a).

Overall results and statistical analysis, the chart clearly shows that plant damage by insect larvae *Cydia fagiglandana* has a severe negative impact on the future ability of germinated seeds to form stems; Thus, healthy plants had a much higher capacity (more than 84%) to form stems than damaged plants (only about 25%). The use of different letters (a and b) indicates a scientifically significant statistical difference between the two situations.

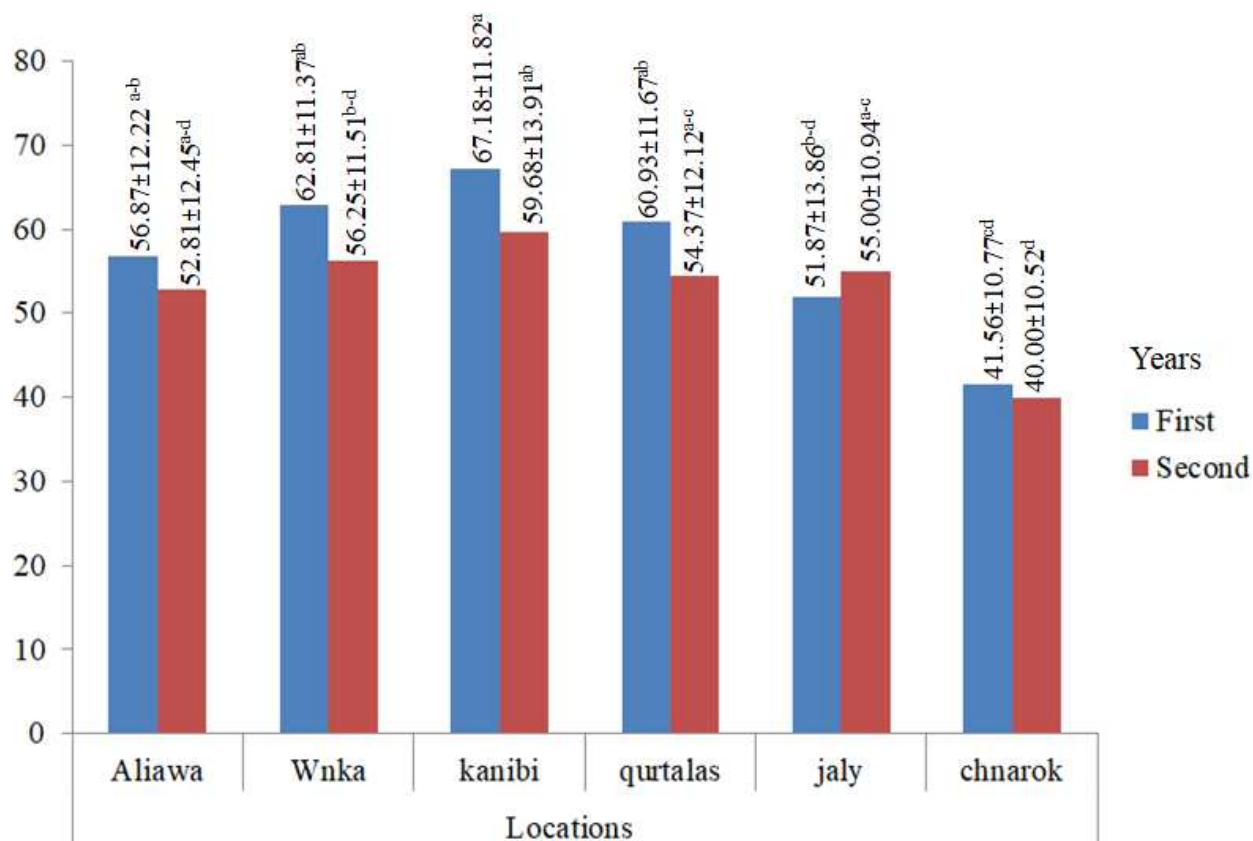


Figure (7): Effect of different forest areas on the percentage of fruit root extraction of *Quercus brantii* acorns during two years of study.

The chart in figure (7) explains the percentage of root removal of *Quercus brantii* acorns according to six different forest regions (Aliawa, Wnka, Kanibi, Qurtalas, Jaly, and Chnarok) for both the first and second years.

Kanibi location the highest root extraction rate was recorded in the first year (67.18 ± 11.82) was marked with the letter (a), and reached (59.68 ± 13.91) with letter (ab) in the second year.

In Wanka area, was (62.81 ± 11.37) was indicated by the letter (ab) for first year, and was (56.25 ± 11.51) was denoted by the letter (b-d) for second year.

Also in Qurtalas, first year the rate reached (60.91 ± 1.67) with letter (ab), and in the second year (54.37 ± 12.12) was indicated by the letter (a-c). In the first year the rate was (56.87 ± 12.22) in letters (a-b), and in the second year (52.81 ± 12.45) was denoted by the letter (a-d) for Aliawa location. In Jaly region, the rate decreased to (51.87 ± 13.86) in letters (b-d) for first year while in

second year (55.00 ± 10.94) in letters (a-c) was recorded. The lowest root removal rate was recorded in Chnarok area, with (41.56 ± 10.77) for first year (cd) and (40.00 ± 10.52) for second year with letter (d).

This analysis shows that despite the temporal difference between the first and second years, geographical factors and location of plant sources have a fundamental impact on the success of post-planting stages (such as stem removal). The large difference between Kanibi (67.18%) and Chnarok (40.00%) raises a scientific question on differences in forest soil composition or effect of stock size in fruits, which must be considered in forest regeneration projects relying on strong zones (Wu, et al. 2022, Shimizu, et al. 2025). These patterns corroborate findings by scholar researchers (e.g., Tilman, 1988; Gallardo et al., 2009) regarding localized edaphic and micro-environmental constraints governing woody seedling establishment (Liu, et al. 2022, Moreno-Valencia, et al. 2024).

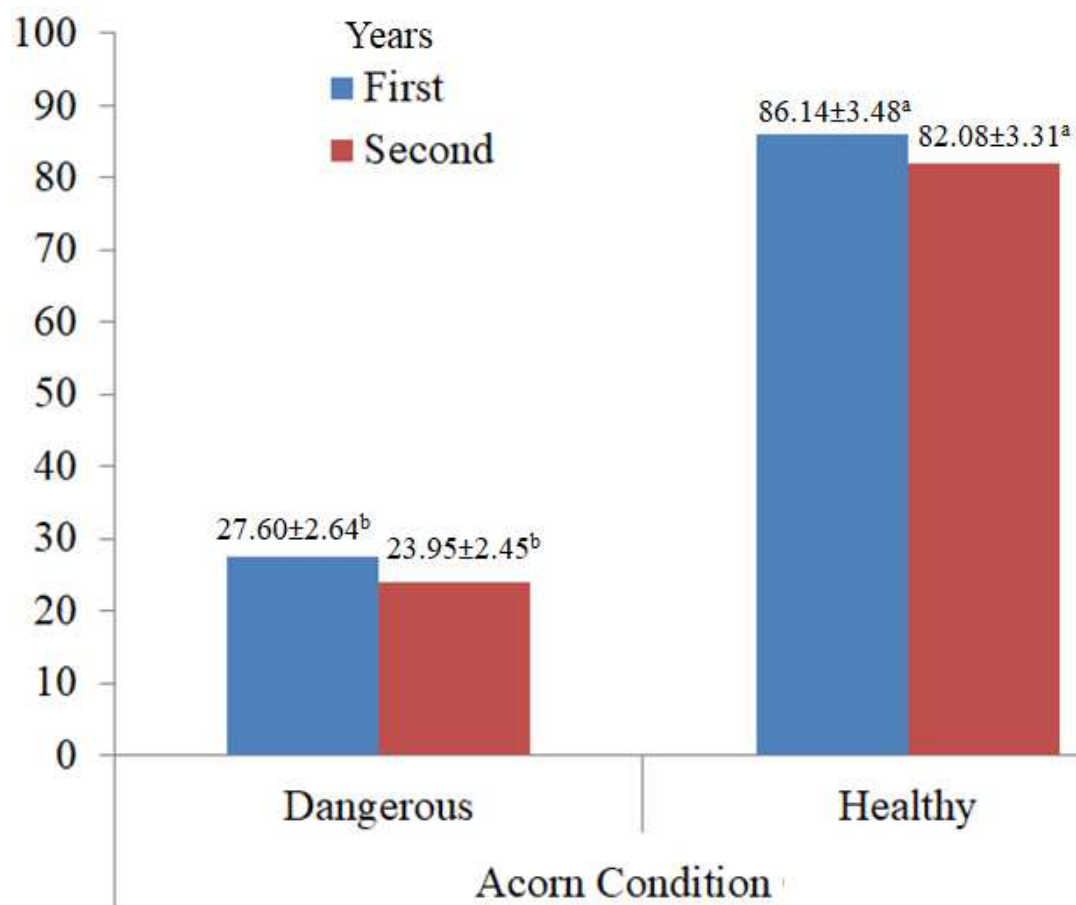


Figure (8): Effect of *Cydia fagiglandana* infestation on the percentage of stem emergence of *Quercus brantii* acorns during two years of study.

The chart in figure (8) explains the percentage of stem removal from *Quercus brantii* fruit according to health status (healthy vs. infected) for two consecutive years. The percentage of stem product in healthy fruits reached a significant difference with (86.14±3.48) for first year and (82.08±3.31) for second year and marked with letter same letter (a) for both year. While in infested fruits the rate was dropped significantly to (27.60±2.64) with letter (b) for first year and was (23.95±2.45) for second year with same letter. The results show a very large and significant difference, with a pattern in which the healthy acorns recorded a higher stem expulsion capacity than the infected acorns. This proves that the infestation of *Quercus brantii* with *Cydia fagiglandana* had a devastating negative and severe effect on the ability of fruits to grow and set in both the years studied.

In terms of year factor, although there was a very slight decrease in the rates in the second year (eg from 86.14% to 82.08% in healthy), this decrease did not have a fundamental impact in both conditions (healthy and affected) (Elkinton 2009). This suggests that the fruit health factor is a more powerful and decisive force than annual differences at this stage of growth. This highlights the overwhelming biotic control exerted by insect herbivory over minor meteorological fluctuations, matching conclusions by (Devirgiliis, et al. 2024) (Dreher 2018) on seed-feeders structuring plant population recruitment dynamics.

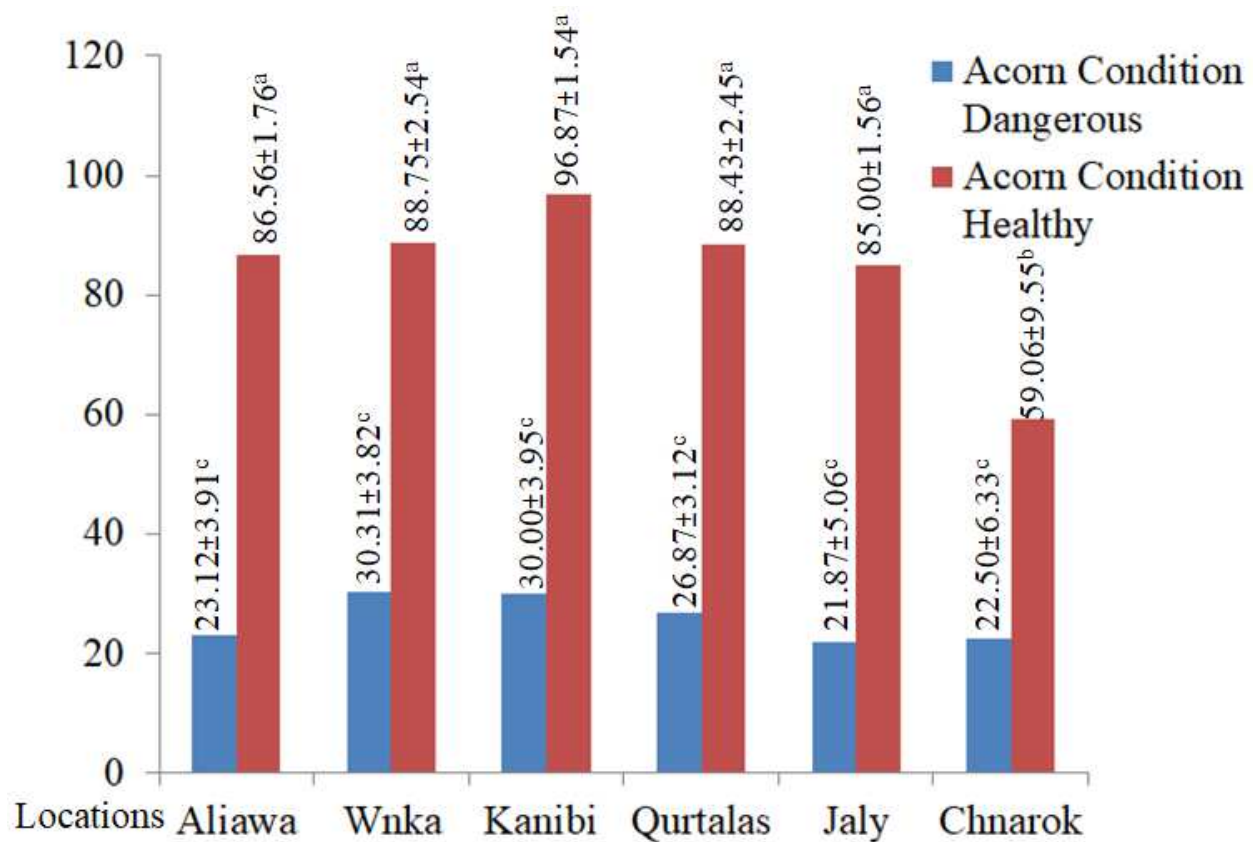


Figure (9): Percentage of stem production by germinated acorns from healthy and *Cydia fagiglandana*-infested seeds collected across six natural *Quercus brantii* forest locations.

The data in chart of Figure (9) illustrated stem production percentage of *Quercus brantii* seedlings collected from six different natural forest areas and compared between healthy fruit and fruit infested with *Cydia fagiglandana*, which are classified here as infested have been done.

Kanibi Forest was recorded the highest success rate of healthy stem formation (96.87 ± 1.54) which carries the letter (^a) which shows the highest level of statistical separation compared to other sites, while the rate for infected acorns was (30.00 ± 3.95) with letter (^c). In Wnka location, stem formation rate in healthy acorns was (88.75 ± 2.54) and marked with letter (^a), while the rate for infected acorns was (30.31 ± 3.82) which carries the letter (^c), which is the highest among infected fruits. The stem production of healthy fruits (88.43 ± 2.45) with letter (^a) and the proportion of infected trees (26.87 ± 3.12) (^c) for Qurtalas forest. In Aliawa forest, the stem formation rate for healthy acorns was (86.56 ± 1.76) (^a), and for infected fruits was (23.12 ± 3.91) (^c). The proportion of healthy acorns reached (85.00 ± 1.56) (^a), while the proportion of infected fruits reached (21.87 ± 5.06) (^c) for Jaly location. Chnarok forest was recorded the lowest level of stem formation in healthy fruits was with (59.06 ± 9.55) carrying the letter (^b), which is significantly different from the other five areas, while the proportion of infected acorns was (22.50 ± 6.33) (^c).

On the red lines (Acorn Condition Healthy) letter (^a) indicates no significant statistical difference between most regions (such as Kanibi, Wnka, Qurtalas, Aliawa and Jaly), all of which are marked with letter (^a) and had high levels of germination. The letter (^b), only in the healthy section of Chnarok (59.06 ± 9.55), which indicates a significant statistical difference compared to other areas, because the rate has decreased significantly. But letter (^c) was distributed on all blue columns (Acorn Condition Dangerous), indicating statistical equality and no significant difference in low stem formation rates among all areas, clearly showing the negative and devastating effect of *Cydia fagiglandana* attack on plant viability and growth. Interestingly, both areas, all damaged plants in these six areas are given only the letter (c). This means that in the case of insect infestation, geographical differences and collection sites have no major effect and insect larval attacks exert similar destructive force in all areas, reducing stem ejection capacity by about 60% to 70% compared to healthy conditions. This uniform suppression across divergent sites underscores the overpowering pathological uniformity of severe cotyledon damage, overriding even favorable local edaphic gradients (Sinclair, et al. 2025).

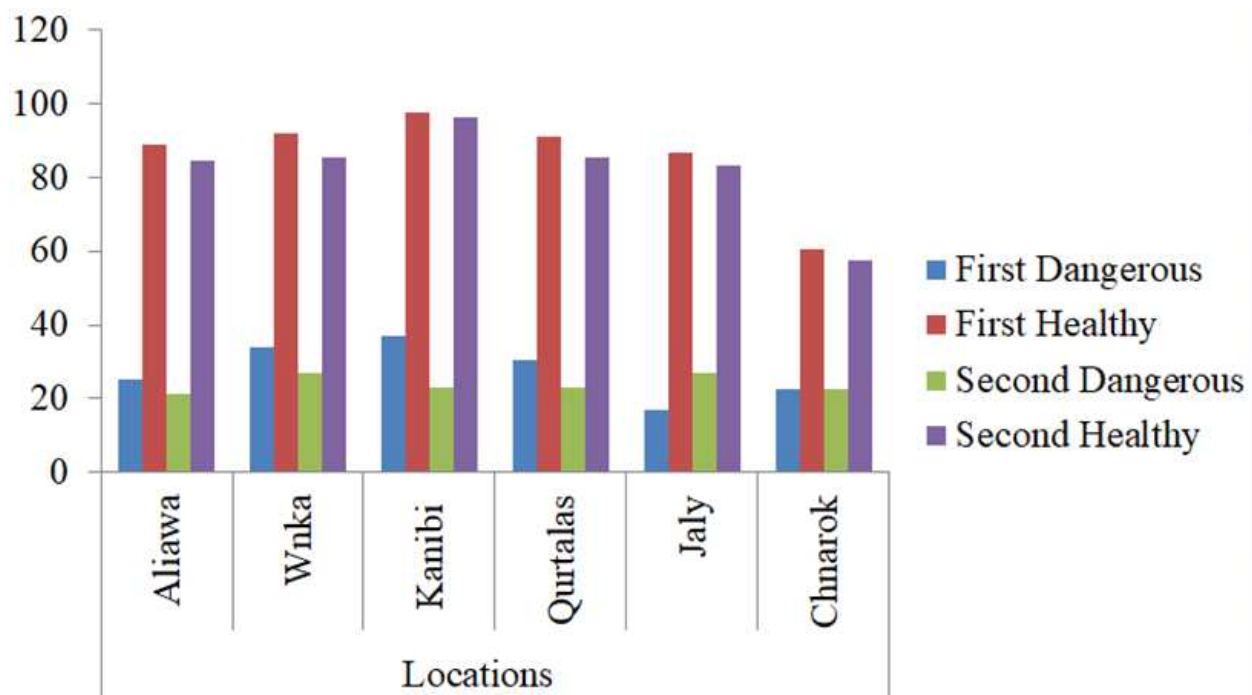


Figure (10): Comparison of stem formation percentages from healthy and pest-infested acorns (*Cydia fagiglandana*) collected across six natural *Quercus brantii* forest locations over two consecutive years (First and Second Years) under experimental conditions.

This statistical analysis in figure (10) was explained the interactive between two-year comparison the health effects of *Quercus brantii* and *Cydia fagiglandana* infected acorns on the percentage of stem formation in six different forest areas.

In first year, Kanibi forest recorded the highest rate of germination and stem formation in healthy acorns was (97.50 ± 2.50) with (^a), while infected faces had (36.87 ± 5.80) with (^c). Also in Wnka, Qurtalas, Aliawa and Jaly forest, the stem formation of healthy acorns reached (91.87 ± 3.73) with (^a), (91.25 ± 4.39) with letter (^a), (88.75 ± 2.60) with letter (^a) and (86.87 ± 2.13) carrying the letter (^a), and reached (33.75 ± 5.15) with (^c), (30.62 ± 2.13) with (^c), (25.00 ± 3.68) carrying the letter (^c) and (16.87 ± 8.68) with letter (^c) for infected acorns respectively. But in Chnarok forest, the lowest and most different levels in healthy fruits recorded (60.62 ± 14.97) carrying the letter (^b), while infected faces (22.50 ± 8.66) with (^c).

In second year, Kanibi location was again led the way with the highest percentage of healthy acorns (96.25 ± 2.16) carrying the letter (^a), while infected fruits (23.12 ± 2.77) with letter (^c)

were recorded. In Wnka, the percentage of healthy seedling of this year was (85.62 ± 3.12) was indicated by the letter (^a), and for infected was (26.87 ± 5.80) with letter (^c). Then in Qurtalas forest, the proportion of healthy fruits was (85.62 ± 1.87) with letter (^a), and infected (23.12 ± 5.62) was denoted by the letter (^c). And in Aliawa, the proportion of healthy acorns (84.37 ± 2.13) with category (^a), and infected trees (21.25 ± 7.46) was indicated by the letter (^c). In Jaly Forest, the proportion of healthy fruits reached (83.12 ± 2.13) was indicated by the letter (^a), and infected (26.87 ± 5.24) was denoted by the letter (^c). Also in Chnarok forest, as in the first year, recorded the lowest level of health acorns (57.50 ± 14.14) with category (^b), and infected (22.50 ± 10.60) with letter (^c).

The data of this statistical analysis show a significant difference between the rate of stem formation in healthy *Q. brantii* and *C. fagiglandana* infested trees in six different forest areas. In both the years of the study, healthy plants consistently showed high physiological potential for greening. In contrast, plants infected with *C. fagiglandana* larvae experienced a significant decrease in greening and growth ability, with stem formation rates falling to the lowest levels in category (^c). This decline is caused by the larvae of this insect entering the core of the plant and feeding on the nutrients stored in the seed (Hietz, et al. 2022). Because the initial development of woody seeds relies entirely on this stored energy and the moisture in the seed, the destruction of the inner seed tissue by the insect results in the loss of the energy needed for root emergence and stem growth. A comparison of these two consecutive years shows that the effect of insects on preventing natural forest regeneration has a stable continuity. While healthy stands in other forests (such as Wnka, Qurtalas, Aliawa, and Jaly) maintained high growth rates that generally ranged from 83% to 92%, the devastating scars of *C. fagiglandana* remained unchanged, reducing success rates to dangerous levels of less than 30%. This temporary stability suggests that seed destruction by this insect is a long-term obstacle to the natural regeneration of deciduous forests in the region (Soheili, et al. 2023). Considering that natural seed development is very important for genetic diversity and survival of deciduous forests to cope with climate change, it is necessary to establish appropriate and healthy control programs for this insect in order to prevent deforestation.



Figure (11): Silent Death: An Investigation into the Causes of Destruction of Old Trees and Natural Sterility of Forests in Wnka Village, the photo taken on 16/10/2025, of *Quercus brantii* on a cemetery in the is a sad as clear example of crisis.

Natural forests, especially those rich in deciduous trees (*Quercus* spp.), form not only the natural character of an area, but also the cornerstone of the local environment (Petros, et al. 2026). Despite the fact that the drying out of older trees is a natural phenomenon that occurs in every forest, what is deeply striking about this forest is the lack of any saplings or young trees to replace the older trees. The drying of these trees creates a large gap in the density of the forest and makes the forest appear patchy and woody. Thus, it loses its environmental character and function. The main reason for this interruption in the forest's generation cycle is the presence of *Cydia fagiglandana* in the area as figure (11). This insect plays a devastating role in destroying the fruit of the trees, in a way that deprives them of the ability to germinate naturally in the area and prevents new seedlings from growing (Wendt, et al. 2021).

4. Conclusion

Infection of *Quercus brantii* with *Cydia fagiglandana* larvae deals a fatal blow to the natural viability of seeds. The destruction of stored nutrients and inner tissues of the plant by the insect causes a significant decrease in root emergence and stem formation by more than 60% to 70% compared to healthy plants. Comparison of the two years of the study shows that the destructive effects of this insect have a continuous stability and do not decrease over the years. This has led

to an interruption of the natural regeneration chain in the forests of the region (as seen in villages such as Wnka and Chnarok), so that the ability of new trees to replace old trees is at zero and threatens total destruction. Geographical assessment showed differences; Areas such as Kanibi had the best and highest growth rates due to their suitable environmental and soil conditions, while Chnarok recorded the lowest growth potential. This proves that because the seed health factor is a dominant force, any future reforestation and replanting projects must rely solely on the collection and application of clean, healthy surfaces in suitable key areas.

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References

1. Radha, K.O. and Khwarahm, N.R. 2022 An Integrated Approach to Map the Impact of Climate Change on the Distributions of *Crataegus azarolus* and *Crataegus monogyna* in Kurdistan Region, Iraq. *Sustainability*, **14** (21), 14621.
2. Ghaedi, Z., Santos, C. and Monteiro, C. 2026 Nature-Based solutions, climate change, and biodiversity: A systematic review of opportunities and risks. *Nature-Based Solutions*, **9**, 100302.
3. Psistaki, K., Tsantopoulos, G. and Paschalidou, A.K. 2024 An Overview of the Role of Forests in Climate Change Mitigation. *Sustainability*, **16** (14), 6089.
4. Wang, L., Wei, F., Tagesson, T., Fang, Z. and Svenning, J.-C. 2025 Transforming forest management through rewilding: Enhancing biodiversity, resilience, and biosphere sustainability under global change. *One Earth*, **8** (3), 101195.

5. Safari, E., Moradi, H., Seim, A., Yousefpour, R., Mirzakhani, M., Tegel, W. *et al.* 2022 Regional Drought Conditions Control *Quercus brantii* Lindl. Growth within Contrasting Forest Stands in the Central Zagros Mountains, Iran. *Forests*, **13** (4), 495.
6. Mirhashemi, H., Heydari, M., Ahmadi, K., Karami, O., Kavgaci, A., Matsui, T. *et al.* 2023 Species distribution models of Brant's oak (*Quercus brantii* Lindl.): The impact of spatial database on predicting the impacts of climate change. *Ecological Engineering*, **194**, 107038.
7. Iordache, M., Marinescu, C., Herbei, M.V., Gaica, I., Dicu, D. and Ianovici, N. 2026 Woody Plant Life-Form Structure Reflects Major Ecological Gradients Within a Protected Temperate Ecosystem from Romania. *Plants*, **15** (8), 1194.
8. Salehi, A., Heydari, M., Poorbabaei, H., Rostami, T., Begim Faghir, M. and Ostad Hashmei, R. 2013 Plant species in Oak (*Quercus brantii* Lindl.) understory and their relationship with physical and chemical properties of soil in different altitude classes in the Arghvan valley protected area, Iran. *Caspian Journal of Environmental Sciences*, **11** (1), 97-110.
9. Manning, A.D., Fischer, J. and Lindenmayer, D.B. 2006 Scattered trees are keystone structures – Implications for conservation. *Biological Conservation*, **132** (3), 311-321.
10. Panzavolta, T., Bracalini, M., Benigno, A. and Moricca, S. 2021 Alien Invasive Pathogens and Pests Harming Trees, Forests, and Plantations: Pathways, Global Consequences and Management. *Forests*, **12** (10), 1364.
11. Ferracini, C., Pogolotti, C., Rama, F., Lentini, G., Saitta, V., Mereghetti, P. *et al.* 2021 Pheromone-Mediated Mating Disruption as Management Option for *Cydia* spp. in Chestnut Orchard. *Insects*, **12** (10), 905.
12. Hashimi, S., Safi, A., Ghanizada, G. and Kamal, S. 2024 Codling moth. *PlantwisePlus Knowledge Bank*.
13. Mei, D., Yu, S., Yu, S., Cao, F., Wang, G. and Dai, T. 2025 Unlocking the Potential of *Sophora moorcroftiana* (Fabaceae): The Overlooked Xizang Endemic. *Forests*, **16** (3), 410.
14. Hacket-Pain, A. and Bogdziewicz, M. 2021 Climate change and plant reproduction: trends and drivers of mast seeding change. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **376** (1839).

15. Timm, A.E., Tembrock, L.R., Zink, F.A. and Mollet, K.A. 2025 A Real-Time PCR Assay for Detecting Codling Moth *Cydia pomonella* on Material Intercepted at U.S. Ports of Entry—A Valuable Tool for Specimen Identification. *International Journal of Molecular Sciences*, **26** (2), 707.
16. Haq, S.M., Waheed, M., Khoja, A.A., Amjad, M.S., Bussmann, R.W., Ali, K. *et al.* 2023 Measuring forest health at stand level: A multi-indicator evaluation for use in adaptive management and policy. *Ecological Indicators*, **150**, 110225.
17. Stamin, F.D. and Cosmulescu, S. 2025 Assessing the Vegetation Diversity of Different Forest Ecosystems in Southern Romania Using Biodiversity Indices and Similarity Coefficients. *Biology*, **14** (7), 869.
18. Olanrewaju, O.S., Glick, B.R. and Babalola, O.O. 2024 RETRACTED: Beyond correlation: Understanding the causal link between microbiome and plant health. *Heliyon*, **10** (23), e40517.
19. Weksler, S., Rozenstein, O., Haish, N., Moshelion, M., Wallach, R. and Ben-Dor, E. 2021 Pepper Plants Leaf Spectral Reflectance Changes as a Result of Root Rot Damage. *Remote Sensing*, **13** (5), 980.
20. Kamanga, R.M., Stevens, J.C., Tuwadala, K., Kachitsa, S.L., Nyasulu, G. and Mwale, V.M. 2026 Morpho-physiological seedling quality assessment of selected ornamental plant species produced by nurseries in Lilongwe, Malawi. *Discover Agriculture*, **4** (1), 145.
21. Liu, X., Xiao, Y., Wang, Y., Wang, R., Huang, R., Liang, H. *et al.* 2024 Seed germination ecology of endangered plant *Horsfieldia hainanensis* Merr. in China. *BMC Plant Biology*, **24** (1), 486.
22. Moreno, M.L., Fernández, M.G., Molina, S.I. and Valladares, G. 2013 The role of small woodland remnants on ground dwelling in-sect conservation in Chaco Serrano, Central Argentina. *Journal of Insect Science*, **13** (1).
23. Hébert, C. 2023 Forest Arthropod Diversity. In *Forest Entomology and Pathology: Volume 1: Entomology*. J. D. Allison, T.D. Paine, B. Slippers and M.J. Wingfield (eds.), Springer International Publishing, Cham, pp. 45-90.
24. Albajes, R., López, M.M. and Jiménez Díaz, R.M. 2026 A claim for plant health as a key component of the one health concept. *One Health*, **22**, 101304.

25. Soler, R., Harvey, J.A., Bezemer, T.M. and Stuefer, J.F. 2008 Plants as green phone. *Plant Signaling & Behavior*, **3** (8), 519-520.
26. Lindman, L., Ranius, T. and Schroeder, M. 2023 Regional climate affects habitat preferences and thermal sums required for development of the Eurasian spruce bark beetle, *Ips typographus*. *Forest Ecology and Management*, **544**, 121216.
27. Zu, J., Xia, J., Zeng, Z., Liu, X., Cai, W., Li, J. *et al.* 2022 Distribution Pattern and Structure of Vascular Plant Communities in Riparian Areas and Their Response to Soil Factors: A Case Study of Baoan Lake, Hubei Province, China. *Sustainability*, **14** (23), 15769.
28. Castro-Alija, M.J., Zolfaghari, G., Fernandez, C.G., Alvarez, C., Ramon-Carreira, L.C., Jimenez, J.M. *et al.* 2024 Elderly Resistance vs. Youthful Acceptance: A Study on Insect Consumption across Age Groups. *Foods*, **13** (16).
29. Petros, G., Maria-Iiada, C., Marianthi, T. and Nikolaos, O. 2026 Biodiversity Hotspots in Peri-Urban Areas: The Case of the Old-Growth Forest Kouri, Thessaloniki, Northern Greece. *Sustainability*, **18** (2), 749.
30. Puig-Gironès, R., Muriana, M., Real, J. and Sabaté, S. 2023 Unravelling the influence of annual weather conditions and Mediterranean habitat types on acorn production, availability and predation. *Forest Ecology and Management*, **543**, 121149.
31. Fang, S., Hu, S., Zhao, B., Chen, D., Lan, C., Li, X. *et al.* 2025 Acorn Weevil Species Diversity and Host Affinity in the Semi-Humid Evergreen Broad-Leaved Forests of Southwest China. *Insects*, **16** (6), 579.
32. Mihai, G., Curtu, A.-L., Alexandru, A.-M., Nita, I.-A., Ciocîrlan, E. and Birsan, M.-V. 2022 Growth and Adaptive Capacity of Douglas Fir Genetic Resources from Western Romania under Climate Change. *Forests*, **13** (5), 805.
33. Whyte, G., Howard, K., Hardy, G.E.S.J. and Burgess, T.I. 2016 The Tree Decline Recovery Seesaw; a conceptual model of the decline and recovery of drought stressed plantation trees. *Forest Ecology and Management*, **370**, 102-113.
34. Mezquida, E.T., Caputo, P. and Acebes, P. 2021 Acorn Crop, Seed Size and Chemical Defenses Determine the Performance of Specialized Insect Predators and Reproductive Output in a Mediterranean Oak. *Insects*, **12** (8), 721.

35. Wu, M.M., Liang, Y., He, H.S., Liu, B. and Ma, T. 2022 Remnant trees location and abundance play different roles in forest landscape recovery. *Forest Ecology and Management*, **511**, 120154.
36. Shimizu, K., Saito, H., Nishizono, T. and Yamada, Y. 2025 Assessing post-harvest forest recovery using Landsat time series in temperate planted and natural forests. *Ecological Indicators*, **180**, 114320.
37. Liu, X., Lan, H., Li, L. and Cui, P. 2022 An ecological indicator system for shallow landslide analysis. *CATENA*, **214**, 106211.
38. Moreno-Valencia, F.D., Plascencia-Espinosa, M.Á., Morales-García, Y.E. and Muñoz-Rojas, J. 2024 Selection and Effect of Plant Growth-Promoting Bacteria on Pine Seedlings (*Pinus montezumae* and *Pinus patula*). *Life*, **14** (10), 1320.
39. Elkinton, J.S. 2009 Chapter 209 - Population Ecology. In *Encyclopedia of Insects (Second Edition)*. V.H. Resh and R.T. Cardé (eds.), Academic Press, San Diego, pp. 826-837.
40. Devirgiliis, C., Guberti, E., Mistura, L. and Raffo, A. 2024 Effect of Fruit and Vegetable Consumption on Human Health: An Update of the Literature. *Foods*, **13** (19), 3149.
41. Dreher, M.L. 2018 Whole Fruits and Fruit Fiber Emerging Health Effects. *Nutrients*, **10** (12), 1833.
42. Sinclair, J.S., Buchner, D., Gessner, M.O., Müller, J., Pauls, S.U., Stoll, S. *et al.* 2025 Effects of land cover and protected areas on flying insect diversity. *Conservation Biology*, **39** (4), e14425.
43. Hietz, P., Rungwattana, K., Scheffknecht, S. and George, J.-P. 2022 Effects of Provenance, Growing Site, and Growth on *Quercus robur* Wood Anatomy and Density in a 12-Year-Old Provenance Trial. *Frontiers in Plant Science*, **Volume 13 - 2022**.
44. Soheili, F., Abdul-Hamid, H., Almasi, I., Heydari, M., Tongo, A., Woodward, S. *et al.* 2023 How Tree Decline Varies the Anatomical Features in *Quercus brantii*. *Plants*, **12** (2), 377.
45. Wendt, M., Senftleben, N., Gros, P. and Schmitt, T. 2021 Coping with Environmental Extremes: Population Ecology and Behavioural Adaptation of *Erebia pronoe*, an Alpine Butterfly Species. *Insects*, **12** (10), 896.