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SUSTAINABLE MANAGEMENT OF SUCKER PROBLEM IN HAZELNUT CULTIVATION

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Abstract: Suckers that develop rapidly in hazelnut bottoms compete with the main branches, resulting in yield and quality losses as well as a risk for pest and diseases. Hazelnut suckers are controlled by mechanical, physical and chemical methods. A majority of mechanical methods are impractical in large production areas and physical and chemical methods come to the forefront. Among the physical methods, flaming is an effective method preferred for this purpose. As a result of studies carried out in different countries on the effect of herbicides on suckers, 2.4-D, glufosinate ammonium, paraquat, carfentrazone-ethyl, and saflufenacil have been recommended. For this purpose, 2.4-D, diquat and glyphosate are applied in Türkiye. Aside from herbicides, some nitrogen fertilizers and plant growth regulators were also effective. In Türkiye, hazelnut growers prefer mechanical and chemical applications for controlling suckers, which they consider as a problem. Within the scope of this study, in order to determine effective, economical, and practical methods and to develop control strategies for Türkiye, a literature review was carried out on the methods for controlling hazelnut suckers in Türkiye and in other countries. In the light of compiled information, current methods and their alternatives have been evaluated. As a result, it is concluded that scientific research is needed and region-specific management strategies should be developed by integrating cultural, physical, mechanical and chemical methods which are effective, economical, and practical for the sustainable management of suckers in hazelnut orchards in Türkiye.

Keywords: Hazelnut, Sucker, Alternative methods, Chemical control, Integrated management

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1. Introduction

Hazelnut (*Corylus avellana* L.) is the second most produced hard-shelled fruit and a widely consumed dried fruit worldwide (Anıl et al., 2018). Turkish hazelnut, grown in the temperate regions of Türkiye, is a preferred product in the international market due to its quality, taste, and variety. The high volume of hazelnut exports indicates the global demand and successful presence of Turkish hazelnut in a competitive market. The total hazelnut cultivation area worldwide reached 1 million hectares in 2020. Türkiye ranked first with a production area of 734 thousand hectares, followed by Italy with 80 thousand hectares, Azerbaijan with 45 thousand hectares, and Chile and Iran both having 24 thousand hectares (FAO, 2022). According to the Black Sea Exporters Association (KIB), the revenue from hazelnut exports in Türkiye was approximately 1.75 billion dollars in 2022, with Germany being the top importing country with an export value of around 490 million dollars (Anonymous, 2022).

Hazelnut is a tree species that grows in shrub form and requires maintenance. Numerous methods must be done in order to produce high-yielding and high-quality products, including irrigation, fertilization, disease, pest, and weed control and management of hazelnut suckers. During the growth season, suckers emerge from adventitious buds at the base of the trunk and develop rapidly each year (Figure 1). Suckers inhibit growth by sharing the nutrients and water of the tree, as well as preventing air circulation and sunbathing in hazelnut hearths. Sucker restricts the growth of hazelnut main branches, leading to a significant decrease in yield, and they serve as a source of inoculum for many plant diseases such as powdery mildew, and create habitats for harmful insects. (Okay et al., 1986; Mehlenbacher and Smith, 1992; Tous et al., 1994; Beyhan and Pınar, 1996; Figen et al., 2021).

Neglecting the regular removal of suckers can have adverse effects on the yield of hazelnut trees and increase the risk of diseases (Karadeniz et al., 2009). It is highly crucial to struggle hazelnut suckers to cultivate high-quality hazelnuts and increase their yield and it is

determined that hazelnut suckers removal twice a year resulted in 42.5% more yield than hazelnut plants that were not treated at all. (Figen et al., 2021). In hazelnut cultivation, it is recommended to control suckers twice a year. These control practices ensure that the suckers in hazelnut orchards are kept under regular control (Okay et al., 1986; Beyhan et al., 1999; Karadeniz et al., 2009; Serdar et al., 2017).

2. Management of Controlling Suckers in Hazelnut Cultivation

Suckers are suppressed by some cultural, mechanical, physical, and chemical methods in different countries. (Figure 2). In Turkish hazelnut orchards, they are controlled through mechanical and chemical methods.

Figure 1. Hazelnut groves with sucker control (a) and without sucker control (b).

Figure 2. Tools and machines used in the control of the suckers, a. Hazelnut knife (Anonymous 2023a), b. Sucker mower, c. Back-mounted flamethrower (Anonymous 2023b), d. Tractor-pulled flamethrower (Anonymous 2023c), e. Steam machine (Anonymous 2023d).

2.1. Cultural Control

Materials in Türkiye, sucker control in hazelnut orchards is typically applied twice a year, usually in July before the harvest and in the fall (October or November). However, some growers may perform this process once a year or once every two years (Kaya, 1986; Kurnaz and Serdar, 1993). When all maintenance operations in hazelnut orchards are calculated in terms of time, the control of bottom shoots, which has a time period of 42%, causes a high labor force, and due to the high labor force, it is applied less than necessary by some growers. It is essential that all hazelnut cultivation practices, including sucker control, are carried out at the right time and frequency.

Hazelnuts are mainly grown in the bottom area (ocak in Turkish) system in Türkiye (Tekgüler, 2021). This system is a multi-stemmed planting system (İslam, 2018) and usually, six or eight saplings planted are around a circle 1–1.2 m in diameter in a bottom area (Beyhan, 2007). The planting method of hazelnut saplings, the number of sapling in each bottom area, and proper pruning of branches are crucial factors that can influence the formation or development of suckers. After planting saplings in the bottom areas, regular inspections should be conducted, and suckers emerging especially in the middle of the bottom areas should be promptly removed to prevent their development. Pruning performed at the right time and using the correct techniques not only positively affects hazelnut yield but also helps to hinder the growth of suckers (Beyhan et al., 1999).

The preference for hazelnut varieties without suckers (*Corylus colurna* L.) has become an important method to facilitate sucker control in hazelnut orchards. The presence of hazelnut trees without suckers in orchards has been found to have both positive and negative effects on hazelnut production (Rovira, 2021). The first trials of *C. colurna* rootstocks, which are suckerless, were conducted between 1940 and 1970 in Oregon, with *C. avellana* rootstocks (Lagerstedt, 1975). The absence of suckers in *C. colurna* trees positively affects hazelnut quality and yield by preventing the diversion of water and minerals from the hazelnut roots to the suckers (Bijelic et al., 2021). This leads to improved quality and higher yield of hazelnuts, enabling better access to underground nutrient sources due to the deep-rooting potential of hazelnut trees. The compatibility of *C. colurna* with *C. avellana* varieties prevents the deterioration of hazelnut trees, making it a positive factor (Mehlenbacher, 1991). Moreover, hazelnut trees without suckers can also exhibit specific characteristics in terms of shell color and texture when compared to *C. avellana* species. However, there are some drawbacks to hazelnut production without suckers. The necessity for hazelnut seeds to be stored for more than two years and the need for at least two years for grafting seedlings extend the orchard establishment process. Additionally, the formation of a taproot with a few lateral roots and the weakness of the root system make hazelnut trees without suckers more susceptible to root diseases and pests. As a result, hazelnut varieties without suckers has significant importance as an alternative solution to sucker control. However, considering both the positive and negative effects is crucial for planning and management when using this method (Bijelic et al., 2021; Pacchiarelli et al., 2022).

2.2. Mechanical Control

In Türkiye, mechanical control of suckers is generally applied manually using some cutting tools such as hazelnut knives or blades, and this practice is commonly mentioned as "cleaning" among the hazelnut growers. Sucker control is one of the most labor-intensive maintenance tasks in hazelnut orchards (İlkyaz, 1986). Moreover, hazelnut orchards' hilly and rugged lands, it may not always be possible to achieve sufficient cleaning. In sloping orchards, finding skilled workers who can clean suckers at the right time and using the correct technique has become a significant challenge (İlkyaz, 1986). Manual sucker control poses the risk of damaging hazelnut branches and roots when performed by inexperienced individuals. Additionally, this process can be time-consuming, physically demanding, and ergonomically challenging, potentially affecting the health of the workers (Kopuzoğlu and Şen, 1991).

To overcome this trouble, some implements and machines (motorised scythe and hazelnut cutter) for using mechanical control of suckers have been developed. Mechanical equipment reduces labor while ensuring a faster and more effective cleaning process. These implements are designed to cut, remove, or clean suckers from the ground. Mechanical cleaning methods not only reduce the workload of workers but also minimize the risk of damaging hazelnut trees (Beyhan et al., 1996).

As a result, keeping up with technological advancements and utilizing mechanization can enable more efficient and cost-effective sucker control. By reducing labor costs, the use of mechanical sucker control implements can encourage growers to be more proactive in managing suckers. The use of these implements for sucker control cause lower labor costs and increase the efficiency. This method helps achieve more effective and ergonomic sucker control in hazelnut orchards. Investing in technological developments and mechanization can provide significant advantages to hazelnut growers in this regard. In Türkiye, some implements have been developed for this purpose and are attached to motorized trimmers to cut the suckers. These implements should be evaluated primarily in terms of effectiveness, and if necessary, effective, practical, and economic implements and machines should be developed and widely used in hazelnut production areas.

2.3 Physical Control

In other countries, physical methods applied for controlling suckers include flame and steam applications. As an alternative approach to control suckers, the use of these methods is also recommended in hazelnut orchards

in Türkiye. Additionally, hot water has been recently used for weed control in different areas, and it could also be used for controlling suckers in hazelnut orchards (Tomasone et al., 2010; Tekgüler, 2021). These physical control methods can provide effective and environmentally friendly alternatives for managing suckers. Their utilization helps reduce the use of pesticides and minimizes environmental impacts while ensuring efficient control of suckers. Research and trials are important to evaluate the effectiveness of hot water treatment on suckers and better understand its applicability in hazelnut orchards (Tomasone et al., 2010; Tekgüler, 2021). The implementation of these alternative methods contributes to sustainable and eco-friendly hazelnut cultivation practices, which can be beneficial for hazelnut growers in Türkiye and around the world.

2.3.1. Flaming

Flaming is a preferred method due to its low cost, ergonomic, and low fuel consumption for sucker control. In Italy, flame applications of 30 and 60 seconds were performed on hazelnut suckers, and the 30-second application was found to be more suitable in terms of sucker management and time efficiency. Applying an average of 6 seconds of flaming to each sucker resulted in moderate to good results (Tomasone et al., 2010). May was recommended for flaming due to the being suckers in the early stage of that period. The most suitable period for this application is early morning or before sunset (Tomasone et al., 2010). Various durations and pressures of flame treatments were applied for controlling suckers in Türkiye. These applications included 30, 60, 90, 120, 150, and 180 seconds of treatment with 1, 2, 3, and 4 bar pressure levels. The most effective application was accomplished with a period of 150 seconds and a pressure of 3 bars which reduce LPG consumption drastically and control the suckers 90% (Tekgüler, 2021). This study represents a valuable research on the combinations of duration and pressure levels to reduce LPG consumption and minimize environmental impact. The results indicate that a 150-second treatment with 3 bars of pressure can be recommended to increase the efficiency of LPG usage and to reduce suckers substantially. Such studies provide important insights into developing strategies for the more sustainable and efficient use of energy resources. Tractor-pulled flame machines are ideal for bigger hazelnut orchards, whereas backpack-mounted flame machines are suitable for smaller orchards. Manual flame method was found to be more effective compared to tractor-pulled flame application for controlling suckers. The narrow spacing between hazelnut trees in the orchards led to adverse effects on the main hazelnut branches and reduced the effectiveness of flame treatment on suckers in the tractor-pulled application. Flame application is advantageous as it also controls weeds in the orchard, in addition to sucker control (Tekgüler, 2021).

2.3.2. Steaming

Steaming is one of the physical control methods used for both weed management and sucker control in hazelnut orchards. A small steam machine was used for steam application in Italy. Steam was applied to hazelnut suckers for a duration of 30-60 seconds to ensure complete contact with the suckers, and the temperature of the steam outlet was measured to reach 300 °Cduring the application. Special equipment or careful monitoring of the steam machine's pipe is required due to the high temperature it reaches during the application (Tomasone et al., 2008). Therefore, steaming needs to be carried out at a slow pace. Compared to flaming, steaming may require more expensive equipment, more fuel, more water, and a longer duration, resulting in more time consumption (Tomasone et al., 2008). Although successful results have been achieved in controlling suckers through the steam application, it was reported that the application needs to be conducted swiftly due to the rapid dispersal of steam into the air (Tomasone et al., 2008).

2.3.3. Hot water application

This application is a cost-effective weed control strategy that is less expensive than the other two physical control methods. Water at 98 °C was sprayed to some weed species (*Plantago major* L., *Amaranthus blitoides* (L.) S. Watson., *Chenopodium botrys* L., *Heliotropium europaeum* L. and *Cynodon dactylon* (L.) Pers.) at three different time periods (morning, noon, and late afternoon) and at different development stages. The best time period for hot water application was discovered to vary based on the weed species and was most effective during the early development stages. The most effective period for application is in the morning or evening hours (Koç, 2019). When examining the effect of hot water on hazelnut suckers, it is hypothesized that this method. It is predicted that this method could yield favorable outcomes for controlling hazelnut suckers.

2.4. Chemical Control

Some organic and inorganic chemicals are also used to suppress hazelnut suckers. Herbicides or other chemical substances can be used to prevent the development of suckers or to completely eradicate them by drying in hazelnut orchards. The use of herbicides for controlling suckers is the most widely used method because of quick implementation and lower cost compared with other methods. Herbicides were first applied in Italy and Oregon (USA) in 1960 for controlling suckers (Serdar and Akyüz, 2017). The effectiveness of herbicides against hazelnut suckers varies depending on the growth stage of the suckers and the number of herbicide applications. Additionally, the droplet size created by herbicide pulverizer also affects the herbicide effectiveness (Creech et al., 2015). However, the chemical substances used for the control of suckers should be applied with caution due to their potential to cause environmental pollution, reduction in soil microbial activity, and phytotoxic effects on agricultural products (Dolci et al., 2000).

2.4.1. Herbicides

The efficacy of some effective substances for controlling

suckers have been studied by many researchers during the early development period of hazelnut. Chemicals containing amitrole, bromacil, cacodylic acid, chlorthiamid, cypromid, dicamba, dichlobenil, dinoseb, diquat, glyphosate, paraquat, picloram, 2,4-dichlorophenoxy-acetic acid (2.4-D), and 2,4,5-trichlorophenoxy-acetic acid (2,4,5-T) were reported to be used against suckers (Reich and Lagerstedt, 1971; Peterson et al., 2016; Pacchiarelli et al., 2022). These substances investigated for their effects on suckers belong to the groups of Auxin, PPO, PSI, and CS in terms of their mode of action (WSSA, 2023) (Table 1).

2,4-D, glufosinate ammonium, paraquat, carfentrazone-ethyl, and saflufenacil were found to be effective against to suckers in Italy (De Souza and Moratti, 2020). Throughout the growing season, multiple applications were recommended for the control of hazelnut suckers (Serdar and Akyüz, 2017; De Souza and Moratti, 2020).

1-naphthaleneacetic acid (NAA) is known as a plant growth regulator that does not have volatile properties. When used above certain doses, it can act as a herbicidal substance that stimulates the production of abscisic acid and hydrogen peroxide, leading to inhibition of plant growth, tissue necrosis, and eventually plant death, or it can be mixed with herbicides. According to recent studies, NAA sprayed on the plant has no negative effect on growth and yield (Dolci et al., 2000; Dolci et al., 2004). In addition, a more effective result was obtained by applying a mixture of NAA and herbicide against suckers (Pacchiarelli et al., 2022).

2.4.2. Nitrogen Fertilizers

Nitrogen is a fundamental macro-nutrient essential for hazelnut, both in the early growth stages of plants and in mature plants. Proper calibration of nitrogen provided through fertilization is crucial to ensure appropriate plant growth and yield.

Table 1. Site actions and chemical group of the herbicides used for suckers control (WSSA, 2023)

Herbicide	WSSA/ HRAC Code	Site of Action	Chemical Group
2,4,5-tricloro-fenoksi-acetic acid (2,4,5-T)	4	Auxin Mimics	Phenoxy-carboxylates
2,4 diclorofenoksi-acetic acid (2.4-D)	4	Auxin Mimics	Phenoxy-carboxylates
Amitrole	34	Inhibition of Lycopene Cyclase (LC)	Triazole
Bromacil	5	Inhbition of Photosynthesis at PSll - Serine 264 Binders (PS II)	Uracils
Cacodylic Acid	0	Unknown	Other
Carfentrazone-ethyl	14	Inhibition of Protoporphyrinogen Oxidase (PPO)	N-Phenyl-triazolinones
Chlorthiamid	29	Inhibition of Cellulose Synthesis (CS)	Nitriles
Cypromid	0	Unknown	Anilide
Dicamba	4	Auxin Mimics	Benzoates
Dichlobenil	29	Inhibition of Cellulose Synthesis (CS)	Nitriles
Dinoseb	24	Uncouplers	Dinitrophenols
Diquat	22	PS I Electron Diversion (PS I)	Pyridiniums
Glufosinate ammonium	10	Inhibition of Glutamine Synthetase (GS)	Phosphinic acids
Glyphosate	9	Inhibition of Enolpyruvyl Shikimate Phosphate Synthase (EPSP)	Glycine
Paraquat	22	PS I Electron Diversion (PS I)	Pyridiniums
Picloram	4	Auxin Mimics	Pyridine-carboxylates
Saflufenacil	14	Inhibition of Protoporphyrinogen Oxidase (PPO)	N-Phenyl-imides

However, excessive nitrogen application can have negative effects on the plant, leading to vegetative abnormalities. The effect of different nitrogen fertilizers (21% ammonium sulfate and 26% calcium ammonium nitrate) at different dosages (0%, 10%, 15%, and 20%) on hazelnut suckers was investigated in Samsun, Türkiye. The 10% solution of 21% ammonium sulfate was found to be effective at a level comparable to herbicides (Serdar et al., 2022). On the other hand, the impact of nitrogen solution fertilizers used in hazelnut orchards on hazelnut yield, shell hardness or softness, and soil properties is not fully understood. However, the general observation is that the use of nitrogen fertilizers in hazelnut orchards provides positive contributions. Nevertheless, while it has been confirmed that nitrogen solutions applied to suckers cause the withering of the suckers, whether they promote the emergence of new suckers is yet to be determined (Serdar et al., 2022).

2.4.3. Inorganic ingredients (Rock Salt)

The use of rock salt at a concentration of 10% is a common practice among hazelnut growers for controlling suckers. However, scientific studies specifically investigating the effects of rock salt on hazelnut suckers have not been reported, yet. When rock salt is applied at a 10% concentration to wet the suckers, it is estimated that approximately 100 grams of salt are applied per bottom area. It is also assumed that a small dose of salt will not have a negative effect on hazelnut trees. To draw a definitive conclusion on this matter, further scientific research is needed to examine the effects of rock salt at different concentrations on the soil, suckers, hazelnut trees, and the quality and yield of hazelnuts. Conducting such research would provide valuable insights into the potential benefits or risks associated with using rock salt for controlling suckers in hazelnut cultivation.

3. Conclusion and Recommendations

Studies conducted worldwide have revealed that various methods are being explored to combat the problem of sucker growth in hazelnut orchards. When comparing their effectiveness and costs, mechanical and chemical control methods have been found to yield the best results. However, it is noted that chemical control should be applied more cautiously due to potential adverse effects. Regarding the application of substances such as nitrogen-based fertilizers and inorganic salts, no conclusive scientific evidence has been obtained on their effects on hazelnut plants, yields, and soil. Therefore, comprehensive studies regarding these practices are needed. Research conducted on sucker growth management in hazelnut orchards highlights the need for careful consideration of the chosen control methods. While mechanical and chemical approaches have proven effective, the potential adverse effects associated with chemical control require diligent application. The long-term effects of substances like nitrogen-based fertilizers and inorganic salts on hazelnut plants, yields, and soil remain inconclusive, underscoring the necessity for extensive research in this regard.

The study on the effects of flaming and steaming on sucker growth has determined that flame application is more effective and economical. All alternative methods should be subjected to necessary scientific research. In order to achieve sustainable hazelnut production and effective sucker growth management, practical and cost-effective methods should be integrated and implemented by growers according to their production areas. Increasing yield and quality in Türkiye, the main producer of hazelnuts in the world, can be achieved by determining and widely implementing successful production and management strategies.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	M.S.B.	Z.F.A.
C	50	50
D	40	60
S	20	80
DCP	70	30
DAI	60	40
L	70	30
W	70	30
CR	30	70
SR	70	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

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