T.R.
ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF HORTİCULTURE

LATERAL SHOOT FORMATION IN CHERRIES

Master's Thesis

Ahmed Abed MOUSA

Supervisor

Prof. Dr. Hüsnü DEMİRSOY

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ACCEPTANCE AND APPROVAL OF THE THESIS

The study entitled **“LATERAL SHOOT FORMATION IN CHERRIES”** prepared by **Ahmed Abed MOUSA**, and supervised by **Prof. Dr. Hüsnü DEMİRSOY**, was found successful and unanimously accepted by committee members as Master thesis, following the examination on the date 29.11.2023 .

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Member	Assoc. Prof. Dr. Dilek SOYSAL Ondokuz Mayıs University Department of Hotıculture	☒ Accept ☐ Reject

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ÖZET

KİRAZLARDA YAN DAL OLUŞUMU

Ahmed Abed MOUSA
Ondokuz Mayıs Üniversitesi
Lisansüstü Eğitim Enstitüsü
Bahçe Bitkileri Ana Bilim Dalı
Yüksek Lisans, Kasım/2023
Danışman: Prof. Dr. Hüsnü Demirsoy

Kiraz ağacı akrotonik büyüme özelliğine sahiptir ve tipik olarak orman ağacı gibi gelişir. Apikal dominansi, kirazların büyümesinde çok önemli bir rol oynar. Bununla birlikte, kiraz ağaçlarında yüksek kaliteli ve bol ürün için optimum ağaç şekli ve bol miktarda sürgün ve yaprak elde etmek insan müdahalesi olmadan zordur. Sonuç olarak, kiraz yetiştiriciliğinde yeterli yan sürgün ve yaprak gelişimini teşvik etmek için çeşitli yöntemlerle çok sayıda çalışma yürütülmüştür. Bu çalışmalar arasında Perlan® uygulaması, budama (tepe kesme), göz yönetimi (göz seçimi, göz çıkarma), çentik atma ve yaralama yer almaktadır.

Bu çalışma, 2021-2023 yılları arasında Ondokuz Mayıs Üniversitesi, Bafra Tarımsal Uygulama ve Araştırma İstasyonunda kirazlarda çeşitli uygulamalarla yan dal gelişimini teşvik etmeyi amaçlamıştır. Çalışmada, Perlan® ($BA+GA_{4+7}$), göz yönetimi ve göz yönetimi + Perlan® uygulamaları 'Early Lory' kombinasyonundaki ağaçlara göz patlamasından hemen önce uygulanmıştır. Denemede çap (mm), boy (cm) ve göz sayısı ile bu gözlerden gelişen sürgün sayısı, kanopi hacmi (m^3) ve ağaç hacmi (m^3) gibi parametreler belirlenmiştir. Deneme sonucunda göz yönetimi + Perlan® uygulamasından erken sürgün gelişimi ve optimum yan sürgün gelişimi elde edilmiştir. Ayrıca, bu uygulama ağaç büyümesini ve ağaç hacmini etkili bir şekilde kontrol etmiştir. Sonuç olarak, göz yönetimi + Perlan®'ın eş zamanlı uygulanmasının, uyumlu bir ağaç büyümesi oluşturmak, bol yan sürgünlerin gelişimini teşvik etmek ve kiraz fidanlıklarında erken meyve vermeyi teşvik etmek açısından oldukça avantajlı olduğu kanıtlanmıştır.

Anahtar Sözcükler: *Prunus avium* L., Göz Yönetimi, Yan Sürgün Gelişimi, Perlan®

ABSTRACT

LATERAL SHOOT FORMATION IN CHERRIES

Ahmed Abed MOUSA
Ondokuz Mayıs University
Institute of Science and Technology
Department of Horticulture
Master, November/2023
Supervisor: Prof. Dr. Hüsnü Demirsoy

The sweet cherry tree exhibits an acrotony growth habit and typically develops like forest wood. Apical dominance plays a crucial role in the growth of sweet cherries. Additionally, achieving optimal tree shape and ample shoots and leaves for a high-quality and abundant crop in cherry trees is challenging without human intervention. Consequently, numerous research efforts have been undertaken in cherry cultivation to explore various methods for promoting the development of sufficient lateral shoots and leaves. These experiments included Perlan® application, pruning (heading), bud management (bud selection, bud removal), notching, and scoring.

The study aimed to encourage the development of lateral branch growth by various applications on sweet cherries in 2021-2023, Ondokuz Mayıs University, Bafra, in Agricultural Research Station. The study applied the Perlan® (BA+GA_{4+7}), bud management, and bud management + Perlan® applications to trees of the 'Early Lory' combination just before bud break. Parameters such as diameter (mm), length (cm), number of buds, the number of shoots that develop from these buds, canopy volume (m^3), and tree volume (m^3) were determined in the experiment. The best results in the experiment were achieved through the combined bud management and Perlan® application. This approach led to more well-developed lateral shoots and promoted precocity, increasing shoot numbers. Additionally, this application effectively controlled tree growth and tree volume. As a result, the simultaneous implementation of bud management and Perlan® proves to be highly advantageous for establishing a harmonious tree growth habit, encouraging the development of abundant lateral shoots, and promoting early fruiting in cherry nursery trees.

Keywords: *Prunus avium L.*, Bud Management, Lateral Shoot Development, Perlan®

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Ahmed Abed MOUSA

CONTENTS

SYMBOLS AND ABBREVIATIONS

SPSS : Statistical Package for the Social Sciences

FAO : The Food and Agriculture Organization

USA : The United States of America

NS : No Significance

GA : Gibberellic Acid

BM : Bud Management

N : Nitrogen

P : Phosphorous

K : Potassium

Ca : Calcium

Mg: Magnesium

Na: Sodium

mg/L : milligrams per liter

cm : centimeter

cm^2 : square centimeter

cm^3 : cubic centimeter

m : meter

mg : miligram

mm : milimeter

kg : kilogram

g : gram

kg/da : kilogram/decar

°C : Celsius

t : ton

FIGURES LEGENDS

TABLES LEGENDS

1. INTRODUCTION

Cherries (*Prunus avium* L.) belong to the family *Rosaceae,* genus *Prunus*. They are among the most widely consumed fruits worldwide, producing approximately 3 million tons annually (FAO, 2022). Sweet-tart stone fruits, like cherries, originate in the region “between the Black and Caspian Seas” in Asia Minor. Due to cherries thriving in temperate climatic conditions, they have naturally extended their cultivation to Anatolia provinces exhibiting continental climate characteristics (Özbek, 1978). Kappel et al. (2012) indeed reported that the center of diversity for sweet cherries (*Prunus avium*) and sour cherries (*P. cerasus* L.) is located in the region encompassing Asia Minor, northern Iran, Syria, Ukraine, and various other countries to the south of the Caucasus Mountains. Several studies, especially in northern Anatolia, have shown that this region is one of the gene centers of cherry (Demir et al., 2011; Demirsoy and Demirsoy, 2003; Erdem et al., 2019; Macit et al., 2020; Köse et al., 2017).

Cherries are delightful small stone fruits in various colors and flavors. They fall into two primary categories: sweet cherries, and sour cherries. These fruits boast a range of essential quality characteristics, including weight, color, firmness, sweetness, sourness, flavor, and aroma (Crisosto et al., 2006).

Their colors span from a yellow to a rich, deep blackish-red. Sweet cherries are a nutritional treasure trove packed with various beneficial compounds, including anthocyanins, quercetin, hydroxycinnamates, potassium, fiber, vitamin C, carotenoids, and melatonin. However, it is crucial to be aware that the levels of these nutrients and bioactive components can be significantly influenced by factors such as exposure to ultraviolet (UV) light, the degree of ripeness at harvest, postharvest storage conditions, and the methods used for processing. These factors play a crucial role in determining the final nutritional profile of sweet cherries, underscoring the importance of handling and processing practices in preserving their healthful attributes. These constituent nutrients and bioactive components contribute to the potential health benefits associated with cherry consumption. Cherries have been linked to reduced cancer risks, cardiovascular disease, diabetes, inflammatory diseases, and Alzheimer's disease. Mechanistically, cherries exhibit notable antioxidant activity, a low glycemic response, COX 1 and 2 enzyme inhibitions, and other anti-carcinogenic effects in vitro

(McCune et al., 2011).

With its appealing and delectable qualities, the cherry has witnessed a surge in demand, particularly in international markets, in recent years (Küden et al., 2001), such as European and American markets. In the last 20 years, progress has been made in factors like tree size reduction, fruit size increase, resistance to cracking, and self-productivity, which has led to significant developments in the world cherry industry. The production and export of cherries are increasing in the world. About 2 732 413 tons of cherries were produced in 2022 (FAO, 2022). In 2022, Türkiye (689 834 tonnes) ranked first, covering approximately 28% of the World's sweet cherry production. In 2021, Türkiye was the top producer of cherries in the world, followed by the United States of America (343 190 tons), Chile (325 048 tons), Uzbekistan (213 600 tons), Iran (156 134 tons), and Italy (93 030 tons) (FAO, 2022). In cherry exports, Türkiye (70 462 tons) ranks third after Chile (335 516 tons) and the USA (73 975 tons) (FAO, 2022).

Cherries are susceptible to various environmental and biological factors impacting their growth and quality. One significant factor is the management of lateral shoots and buds, which are crucial in cherry production. These lateral shoots thrive, similar to forest wood, due to apical dominance. Cherries set their fruit on spurs on old shoots and at the lower parts of one-year-old branches. Consequently, it is necessary to train and manipulate cherry trees to encourage the development of lateral shoots for successful commercial production. This process is also essential for shaping the tree at an early stage. Various methods can be employed to stimulate the growth of lateral shoots in cherry trees, including heading, tipping, pinching, scoring, notching, and using specific chemicals. However, many of these applications are labor-intensive and time-consuming. Therefore, chemical practices that save labor and time have gained prominence in cherry cultivation. Indeed, various chemicals like Promalin/Perlan®, Cyclanilide, Arbolin, and Paturyl have been employed to manipulate cherry trees to encourage the development of lateral shoots for successful commercial production, as noted by Jucyna et al. (2005) and Elfving and Visser (2007). Proper application and a balanced approach are essential to achieving the desired results in plant growth and branching.

Developing lateral shoots in cherry trees is essential in maintaining the tree's structure and overall productivity. These lateral shoots originate from dormant buds located along the main branches of the tree and have the potential to grow into new fruit-bearing branches, which are responsible for producing cherries. As a result, effective management of lateral shoots becomes essential in controlling cherry yields and ensuring the tree's health. However, it is crucial to strike a balance in the growth of lateral shoots. Excessive growth can lead to overcrowding, reduced air circulation, and shading, negatively impacting fruit quality and quantity. Conversely, insufficient lateral shoot growth may result in fewer fruit-bearing branches, potentially reducing overall yield. Therefore, finding the proper equilibrium in lateral shoot management is critical to optimizing cherry production while maintaining fruit quality and tree vigor (Lang, 2001).

Apical dominance, where the terminal bud is dominant and lateral shoot development is prevented, is quite common in cherries. Apical dominance means that the main apical tip of the tree exerts control over the growth of lateral shoots. Apical dominance occurs because young leaves at the tree's uppermost point, particularly in the vegetative tip, produce a hormone called auxin. This hormone then moves downward, effectively suppressing the growth of lower-ranking lateral buds (Stanisavljević et al., 2015; Sazo and Robinson, 2011). Understanding and effectively managing this hormonal balance are pivotal for controlling lateral shoot growth in cherry trees.

Another practice used to ensure tree growth and development in cherry cultivation is bud management. This practice involves carefully selecting which buds to remove or retain to exercise control over shoot growth and encourage the emergence of lateral shoots. Effective bud management serves several vital purposes, including regulating the vigor of cherry trees, striking a balance between vegetative and reproductive growth, and enhancing the overall quality and yield of the fruit (Macit et al., 2017; Greer and Weedon, 2016).

Furthermore, strategies for bud management can optimize the utilization of growth resources such as sunlight, mineral nutrients, products of photosynthesis, and water (Lang et al., 2007). This approach to tree development minimizes the necessity for future summer and winter pruning, streamlining the management of cherry trees and contributing to their overall health and productivity.

The bud removal technique is a relatively recent innovation initially employed in Europe. As Lang (2001) reported, this method proves valuable in curbing excessive early spur and fruit formation. However, it is worth noting that it may lead to the emergence of more vigorous and upright shoots.

The primary benefit of bud removal lies in its effectiveness in limiting shoot growth in the upper one-third of the tree's leader while encouraging shoots to develop in the middle and lower one-third of the leader. Furthermore, bud removal can serve as a stimulus for branching on scaffold branches and the leader itself. The development of secondary branching on scaffold branches holds particular importance in the early training of high-density sweet cherry trees (Lang, 2001). This technique presents a promising approach to cherry tree management, encouraging balanced growth and enhancing fruit production.

There is a rising interest in incorporating plant growth regulators (PGRs) into managing lateral shoot formation and bud development in cherry trees, complementing traditional pruning techniques that have been utilized for long years. Cherry trees, known for their fruit-bearing capabilities, can also benefit from using these plant growth regulators, as Suman et al. (2017).

One notable plant growth regulator (PGR) is Perlan®, which combines two plant hormones: cytokinin and gibberellin. Perlan® is recognized for its ability to encourage cell division and overall plant growth. In contrast, gibberellins have a role in stimulating stem elongation, enhancing fruit growth, and facilitating seed germination, as discussed by Chauhan et al. (2020).

Research studies have provided compelling evidence that using Perlan® and gibberellin can significantly enhance yields and improve the overall quality of cherry fruit. For example, in a study conducted in Türkiye, the application of Perlan® and gibberellin to cherry trees resulted in increased fruit weights, larger fruit sizes, and higher sugar content (Canli et al., 2015). Furthermore, another study demonstrated that applying gibberellin delayed harvest by two weeks and reduced the fruit's susceptibility to bruising. In addition to these benefits, fruit size, firmness, and soluble solids content notably improved, as Einhorn et al. (2013). These results underscore the advantages of utilizing plant growth regulators in cherry cultivation, improving yields and superior fruit quality.

In short, effective management of lateral shoots and buds plays a crucial role in cherry tree care, significantly impacting both cherry production and tree health. Proper management techniques like pruning and using plant growth regulators (PGRs) can boost yields, enhance fruit quality, and sustain the tree's vitality. Conversely, inadequate management practices can decrease productivity and harm growers economically. Therefore, it is essential to conduct further research to fine-tune the practices of lateral shoot and bud management in cherry production.

This study aimed to determine the effect of Perlan® ($BA+GA_{4+7}$), bud management, and bud management + Perlan® applications on lateral shoot formation in cherries.

2.REVIEW OF LITERATURE

Miller (1983) conducted a study that explored the utilization of Promalin to manipulate the growth and fruit production in one-year-old sweet cherry trees. Promalin, which consists of a combination of 6-benzylamino purine plus gibberellins A4 + A7, was found to enhance the development of spurs and lateral shoots when applied as paint to one-year-old wood in several sweet cherry cultivars. The researcher observed that although applications close to bud burst were slightly more effective, positive responses were achieved regardless of the timing within the 10-to-18-day period from bud swell to bud burst. Additionally, they found that brown paint was a more effective carrier for Promalin than white paint. One noteworthy study result was that Promalin led to localized increases in axillary development precisely above the treated area, with no impact observed below it. This increased spur and lateral shoot development significantly boosted flowering and fruit production in subsequent growing seasons. However, it is essential to note that sprayed applications of Promalin after bud burst, did not influence axillary development and even reduced the following year's bloom. While there were variations in how different cherry cultivars responded to painted applications of Promalin, the study highlighted the potential of Promalin as a valuable tool for managing young cherry trees' growth and fruit production.

Greene and Autio (1994), the researchers explored “notching techniques to enhance branching in young apple trees. This technique involved using a hacksaw blade to carefully remove a 2-mm-wide strip of bark directly above a bud. The cut extended to the secondary xylem, encompassing roughly one-third of the stem's circumference. The study found that the most effective timing for notching was approximately 2 to 4 weeks before full bloom. Notching was particularly successful in stimulating shoot growth from buds on a branch's upper portion. It was less effective for buds on the sides of the branch and least effective for buds on the underside of the branch. In untreated control trees, most shoots develop from the upper one-third of one or two-year-old growth, with very few shoots developing from buds on the lower one-third of the growth. However, a similar habit was noted when a bud was notched, although the occurrence of shoot development was notably higher. The study also revealed that the percentage of notched buds developing into shoots was not influenced by the age of the wood. Moreover, there was a positive and linear relationship between the bud size, the percentage of buds developing into lateral shoots, and the length of those lateral shoots. Notching consistently resulted in increased shoot production across different years, experiments, and apple cultivars. This research underscores the effectiveness of notching techniques in promoting branching and shoot growth in young apple trees.

Savini et al. (2004) explored two techniques for shaping lateral shoot growth in young fruit tree nursery trees: disbudding and leaning. Disbudding involved removing specific lateral buds before they sprouted, resulting in more even lateral shoot growth along the stem and varying the number of lateral bud pairs impacted shoot length, with more pairs leading to shorter shoots and leaning the trees slightly during planting influenced bud growth favoring the lower stem parts. The most uniform lateral shoot growth was achieved when disbudding and leaning combined. This suggests these techniques work well together in shaping lateral shoot development for fruit tree nursery trees, which can be valuable for orchard management and production.

Elfving and Visser (2006) conducted a study comparing the performance of a new bioregulator called cyclanilide (CYC) with a proprietary formulation of 6-benzyl adenine and GA_{4+7} (Promalin). The study focused on lateral branch development in sweet cherry trees. Here are the key findings of their study: CYC was found to effectively stimulate the formation of lateral shoots on the current season's shoot growth. This effect was observed both in orchard and nursery conditions. CYC demonstrated similar or superior effectiveness in promoting "feathering" in the nursery setting compared to (PR) across various cherry cultivars tested. When CYC and PR were mixed in tank mixes, no synergistic effects on feather development were observed. This suggests that the two substances did not enhance each other's effects in this context. The crotch angles of feathers induced by CYC were similar to those of feathers that naturally formed on the trees. This indicates that the induced lateral branches did not differ significantly in their growth habit. The growth stimulated by CYC-induced feathers was sufficient to produce trees of acceptable quality in the nursery. CYC did not significantly affect the trunk caliper of nursery trees, or any effect observed was minimal. The study concluded that cyclanilide (CYC) is an effective bioregulator for promoting lateral branch induction in sweet cherry trees, particularly in a nursery setting. It proved to be as effective as or even better than the proprietary (PR) formulation across various cherry cultivars tested. The induced branches exhibited consistent growth habits and did not negatively impact the overall quality of nursery trees.

Jacyna and Lipa et al. (2008) investigated methods to induce. The study focused on the development of lateral shoots in unpruned leaders of young sweet cherry cultivars 'Regina' and 'Schneiders' grafted on Mazzard rootstock. They found that applying acrylic paint containing a mixture of 5 g/L of BA (6-benzyladenine) and GA_{4+7} (gibberellins A4+7) to the lower one-third to one-half of the tree leader between bud swell and bud burst effectively induced lateral shoots, with the induction zone confined to the application area. Additionally, tipping the upper one-third of the leader and treating the remaining portion with BA + GA_{4+7} produced similar results. Disbudding, involving selective bud removal, had minimal impact on lateral branching in unpruned sweet cherry tree leaders. Both 'Regina' and 'Schneiders' cultivars responded similarly to the treatments, emphasizing the efficacy of paint application and leader tipping with chemical treatment for lateral shoot induction in unpruned sweet cherry tree leaders, with limited induction beyond the treated area. These findings hold significance for sweet cherry cultivation and branching management.

Koyuncu and Yıldırım et al. (2008) conducted a study to examine how different doses of Perlan® (0, 100, 250, 500, 750, and 1,000 ppm) affected the growth of 0900 cherry cultivars in nursery conditions. They found that using Perlan® significantly boosted the plant's diameter compared to the control group. Additionally, the application of Perlan® resulted in wider branch angles. Notably, the highest branch formation in seedlings was observed when Perlan® was applied at a concentration of 500 ppm.

Bennewitz et al. (2010) investigated the impact of Promalin application at various phenological stages and notching at different distances on three cherry cultivars' side branches. The findings indicated a significant increase in the total length of side branches, specifically in the ‘Bing’ cultivar, compared to the control plants. Moreover, the total growth of side branches was twice as much as that observed in the control trees. For the Lapins cultivar, it was observed that the total number of lateral branches increased significantly. However, compared to the control group, no significant differences were observed in terms of the total length of lateral branches and the number of lateral branches in the Stella cultivar.

Elfving et al. (2011), They experimented with treatments on 1-year-old leader branches of 'Skeena'/Mazzard sweet cherry trees. They applied various solutions, including GA_{4+7} alone, benzyladenine alone, Prestige, and Thidiazuron, combined with ProVide, using Regulaid as a surfactant. The results showed that GA_{4+7} alone was nearly as effective as benzyl adenine and more effective than Prestige or Thidiazuron alone in promoting lateral shoot growth. Combining GA_{4+7} with Prestige or Thidiazuron yielded similar results to GA_{4+7} alone. Additionally, these treatments improved vertical shoot distribution, albeit with slightly shorter shoots. In summary, GA_{4+7}, alone or with cytokinins, enhanced lateral shoot development and vertical shoot distribution in 'Skeena' sweet cherry trees, with only a minor impact on mean shoot length.

Moghadam and Zamanipour (2013) conducted two separate experiments to enhance the growth of one-year-old sweet cherry nursery trees, specifically the ‘Siah Mashhad’ and ‘Dovomras’ cultivars. The primary goal was to improve lateral shoot formation and overall tree quality. In the initial experiment, various heading treatments were applied at heights above the ground (0, 40, 60, and 80 cm). In the second experiment, Arbolin treatments were foliar applied at different concentrations (0, 5, 15, 25 mL.L-1), with applications occurring twice at 7-day intervals in mid-June. The results of these experiments revealed that all treatments led to an increase in the number of lateral shoots compared to the control group, regardless of the cherry cultivar. Notably, heading 60 cm above the ground emerged as the most effective treatment for enhancing the total number of lateral shoots. Furthermore, the second experiment demonstrated significant variations between cultivars and the Arbolin treatments. Higher concentrations of Arbolin and repeated applications positively impacted the number of lateral shoots in both cultivars. Interestingly, Arbolin treatments exhibited a more pronounced and highly significant effect on the number and length of lateral shoots when compared to heading treatments.

Moghadam and Zamanipour (2013) investigated the effects of summer pruning and crop loading on sweet cherry trees. They studied carbohydrate levels in summer and winter buds, and their impact on bud burst and fruit quality in two cherry cultivars. Summer pruning reduced non-structural carbohydrates (NSCs) in late summer buds, with minor winter effects. Early pruning improved fruit quality the following season. A high crop load increased NSCs in winter buds. Sucrose levels in winter buds varied among cultivars and affected bud burst rates in the following season.

McArtney and Obermiller (2015) investigated the effects of benzyl adenine (BA) treatment on one-year-old sweet cherry nursery stocks, both during dormancy and via notching treatment. They discovered that BA treatment during dormancy significantly promoted current shoot development, with a notable difference between treated and untreated groups. Notably, nursery stocks treated with 600 and 1200 mg/L of BA exhibited significantly more significant enhancement than those treated at 300 mg/L. Combining BA spray with notching increased current shoot numbers and influenced their area and development angles, with the most effective results observed in early March before sap flow began. This combined approach yielded high-quality nursery stocks well-suited for hedgerow training.

Stanisavljević et al. (2015) conducted a study focusing on the techniques for inducing lateral shoots in sweet cherry cultivars grafted onto the Gisela 6 rootstock. They experimented with various combinations of plant growth regulators, specifically 6-benzyladenine, gibberellic acid 4 and 7 ($BA+GA_{4+7}$), and cyclanilide. The cherry cultivars they examined were 'Carmen,' 'Grace Star,' and 'Black Star.' Among the cultivars studied, 'Black Star' exhibited the highest number of induced lateral branches. The application of $BA+GA_{4+7}$ treatment increased the number of lateral shoots in all the cultivars compared to the control group. The most noteworthy enhancement in the number of branches was achieved using Cyclanilide treatment. This treatment increased the number of lateral shoots and improved their distribution, resulting in more uniform shoot lengths. Interestingly, when they combined Cyclanilide treatment with $BA+GA_{4+7}$, they did not observe a synergistic increase in the number of branches compared to the effect of Cyclanilide treatment alone.

Rutkowski et al. (2015) investigated the impact of tree pruning intensity on the yield and fruit quality of one-year-old budded sour cherry plants of the 'Łutówka' cultivar over five years spanning from 2006 to 2010. They implemented three distinct pruning regimes: no pruning, moderate traditional pruning involving branch shortening, and intensive pruning with removing branches older than three years. The study revealed that the prevailing weather conditions significantly influenced tree yield during the experimental years, and as pruning intensity increased, yields tended to decrease. However, the extent of these effects varied depending on the specific year and orchard conditions.

Macit et al. (2017) investigated the impact of bud management techniques on sweet cherry trees in Samsun, Türkiye, between 2010 and 2014, focusing on cultivar/rootstock combinations such as ‘0900 Ziraat’ grafted onto M × M 60, Sweetheart grafted onto M × M 60, ‘0900 Ziraat’ grafted onto Gisela 5, and ‘Regina’ grafted onto Gisela 6. The study revealed that bud management led to several favorable outcomes, including more uniform branching along the leader, a denser canopy with reduced empty spaces, faster and healthier canopy formation, shorter and evenly sized branches, an increase in 2-year-old shoots capable of fruit production, and earlier attainment of maximum productivity. These findings underscore the effectiveness of bud management in enhancing the growth and yield potential of sweet cherry trees, particularly in specific cultivar/rootstock combinations.

Toprak et al. (2018) investigated the influence of Perlan® and bud management techniques on the growth, lateral shoots, and early fruiting of cherry nursery trees, emphasizing the ‘Regina’/CAB 6P combination. These techniques were applied just before bud break, aiming to assess their effects on the development and productivity of the cherry trees. These “applications significantly” influenced the diameter, length, and number of primary shoots on the central leader and the number of 2-year-old shoots capable of bearing fruit. Additionally, they improved leaf area and overall tree volume. Notably, combining bud management with the Perlan® application showed the most favorable results. This study underscores these practices' effectiveness in enhancing cherry nursery trees' development and productivity.

Gündüz (2019) conducted a study to assess the influence of different branching methods, including the application of 6-Benzyladenine (BA) and Perlan® containing GA_{4+7} at concentrations of 0 ppm, 500 ppm, and 1000 ppm, administered three times at one-week intervals, on apple, pear, cherry, and mulberry saplings. Notable findings include the positive effect of Perlan® applications on sapling length and shoot development in all fruits except pears. The 500 ppm Perlan® application was most effective in promoting lateral branch formation, with pinching applications particularly effective in apple cultivars. Perlan® applications also effectively increased the number of branches, root diameter in pears and apples, and seedling diameter across all types and cultivars. Additionally, cherry cultivars benefited from pinching applications regarding side branch angles, while other fruits and cultivars saw benefits from the 500 ppm Perlan® application.

Lanar et al. (2020) conducted a study to enhance branching in nursery apple and plum trees using various methods, including chemical treatments (benzyl adenine - BA and gibberellins - $GA_{4/7}$), mechanical techniques (leaf pinching) and combinations thereof. The research, spanning 2015 and 2016, aimed to increase the number and length of sylleptic side shoots, known as "feathers" on apple cultivars ('Rubinola' and 'Topaz' on M9 rootstock) and plum cultivars ('Elena' and 'Tophit' on St. Julien A rootstock). Results showed that in apple cultivars, BA application four times yielded the highest numbers of feathers, mainly shorter ones, while leaf pinching proved less effective. In plum cultivars, BA application four times also resulted in the highest feather numbers, particularly in the 1-10 cm and 10-30 cm length categories. Remarkably, unlike apples, plum cultivars exhibited improved growth of feathers longer than 30 cm when pinching was utilized, suggesting potential effectiveness for organic production.

Neri et al. (2007) developed a small open vase training system fully manageable by the ground with 550 trees per hectare to obtain dwarfed, easy-to-manage pear trees while maintaining vigorous rootstocks' autonomy. They used local 'Pera Angelica di Serrungarina' (also called 'Santa Lucia') clones on different rootstocks, including 'BA29, 'Farold 40, and 'micro propagated 'Conference.' Their approach allowed strong rootstock vigor to be directed into multiple shoots, promoting early fruiting. BA29 had the highest flowering intensity, 'Farold 40' performed moderately, and 'Conference' had the lowest flowering rate. They applied iron chelates and organic fertilizer to combat nutrient deficiencies, particularly on 'BA29' and 'Farold 40'. These findings offer insights into optimizing pear tree cultivation.

3. MATERIALS AND METHODS

This study was conducted at OMU's Agricultural Practice and Research Center in Bafra from 2021 to 2023.

3.1. Materials

In the study whip-shaped nurseries were used and planted in November 2021 (Figure 3.1). Nursery trees have planted in January in 2021 as whips. Central leader have been used as the training system. ‘Early Lori’ cultivar grafted on ‘Gisela 6’ rootstock was used in the study.

The experiment involved a total of four applications, including control applications. These applications comprised Perlan® ($BA+GA_{4+7}$), bud management, Perlan® + bud management, and the control group. The experiment was conducted with eight replications, each consisting of 3 trees. It was established following a randomized plots experimental design, resulting in 96 saplings being included in the study.

Figure 3.1 Planting of nursery trees in the experiment in 2021.

3.1.1 Description of Experimental location

The trial area is at an elevation of 16 meters above sea level and at coordinates 35º52'17" E and 41º33'50" N in the Bafra district. Bafra district experiences a typical Black Sea climate, characterized by the warmest conditions in July and August and the coldest conditions in January and February. The annual precipitation in the county ranges from approximately 750 to 1000 mm dry and hot winds from the southwest and south dry the region, reducing humidity levels. On average, the relative humidity in the district stands at 73% (MGM, 2022).

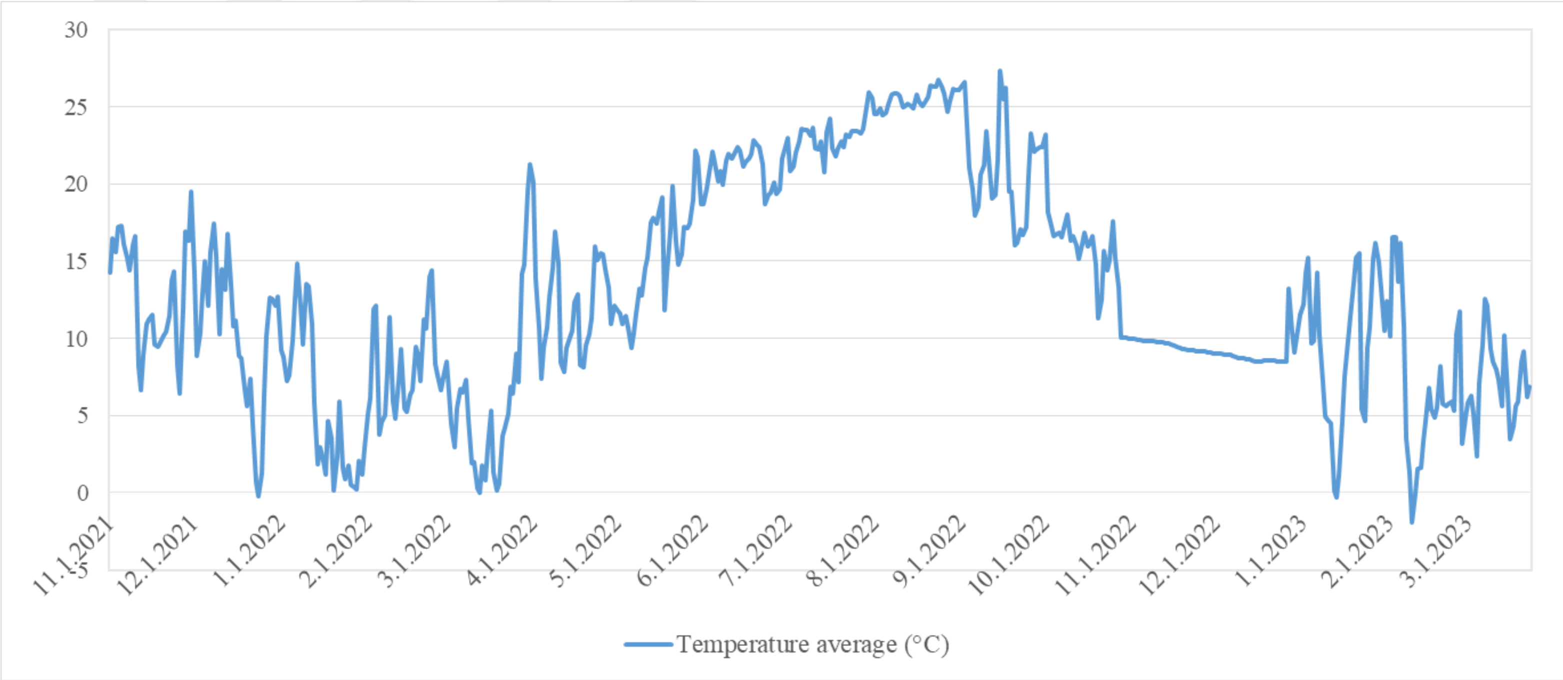

Figure 3.2 The average temperature data for the experimental site in degrees Celsius (°C).

3.1.2. Soil characteristics of the experimental area

The soil at the experimental site was characterized as a silty clay loam with the following composition: 33.73% clay, 55.35% silt, and 10.92% sand. The oxidizable organic matter content was measured at 2.71%, falling within the moderate range. The soil pH was 8.03, indicating alkaline conditions. The soil's electrical conductivity (EC) was 0.55 ds.m/L. Lime content was relatively high at 10.28%, and the total nitrogen (N) content was 0.062%, which is considered low. Available phosphorus content was 31.49 mg.kg-1, indicating a high level. Additionally, the exchangeable levels of potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg) were 0.34 (moderate), 1.12 (high), 21.00 (very high), and 6.80 (high) mmol (+) Kg/L, respectively (Table 3.1).

In response to these soil analyses, two shovels of decomposed farm manure were applied to all saplings to increase the organic matter content in the soil.

Table 3.1 Soil properties of the experiment site

Clay	38.24 %	Total N content	0.08 % (low)
Silt	36.11 %	P content	136.2 mg kg^{-1} (very high)
Sand	38.24 %	K	0.81 cmol (+) kg^{-1} (moderate)
Organic matter	1.12 % (low)	Na	0.56 cmol (+) kg^{-1}(moderate)
pH	7.18	Ca	34.40 cmol (+) kg^{-1} (very high)
EC	0.48 dS m^{-1} (nonsaline)	Mg	7.70 cmol (+) kg^{-1} (high)
Lime content	19.76 % (moderate high)		

3.1.3 Characteristics of the cultivar and rootstock used in the experiment

‘Early Lory’

‘Early Lory’ is a cultivar of cherries known for its early ripening season, typically in late May to early June, depending on the location. It is a sweet cherry cultivar with bright red skin, and firm flesh. ‘Early Lory’ cherry is characterized by its medium size and delightful flavor profile, making it a favored option for fresh consumption and baking. This cherry cultivar is frequently cultivated in the Pacific Northwest region of the United States, with a particular emphasis on Washington State, renowned for its thriving cherry production industry. This cultivar is also grown worldwide, including Canada, Europe, and Türkiye (Anonymous, 2023).

‘Gisela 6’

‘Gisela 6’, a rootstock developed in Germany through the hybridization of *Prunus cerasus* and *Prunus canescens* has earned global recognition for its adaptability and advantages. It stands out for its versatility, requiring less exacting soil quality, water supply, and cultural management when compared to ‘Gisela 5’. A moderate level of vigor strikes a balance between growth habits, making it suitable for less intensive cultivation. Notably precocious, ‘Gisela 6’ trees bear fruit early in their lifespan, ensuring productivity and ease of management, especially under irrigated conditions. This rootstock is particularly well-suited for orchards on lighter or less irrigated soils and is an excellent choice for transitioning from vigorous to size-reducing rootstocks. It is a popular choice in the United States, often for orchards with permanent scaffold training and more extensive plant spacing.

3.2 Methods

To promote the formation and growth of lateral shoots in the trial, three treatments were applied to the trees just before bud break at the green tip stage. These treatments included Perlan® application, bud management, and a combination of bud management plus Perlan®, alongside a control group for comparison (Figure 3.3).

Figure 3.3 Bud development at the time of Perlan® application

3.2.1 Perlan® application

Perlan®'s commercial formulation containing N-(phenylmethy1) (H- Purin- 6 amine plus gibberellin A4 + A7) was employed in the experiment. This formulation comprises 18.5 g/L gibberellic acid (GA_{4+7}) and 18.8 g/L benzyl adenine (BA), Veinbrants and Miller (1981). To apply Perlan®, it was mixed at a ratio of 1:3 with water, and Tween 20 was included as an adhesive for all cherry trees.

It is important to note that Perlan® is recognized for not adversely affecting buds or branching when applied at temperatures below 16°C, Demirsoy (2015) and Toprak et al. (2018).

Therefore, in this study, Perlan® was applied under calm, open-air conditions with temperatures exceeding 16 °C in spring 2022. For the control group, tap water with a pH of 7.3 was used in the experiment for spraying, as depicted in Figure (3.4).

Figure 3.4 Perlan® application method and the condition of the bud during application

3.2.2 Bud Management

One of the methods used successfully in shaping cherry trees is bud management, which is done in the form of bud removing or bud selection. The bud management center provides the formation of side branches with more regular intervals and wider joining angle on the leader. Bud plucking is done after the buds are swollen, before shoot growth begins.

In terms of bud management, the selection of seedlings is an important criterion at the stage of establishing a orchard. Since our goal is to break the wild growth habit of cherry with bud management techniques, it would be better to turn the branched saplings, which are often far from ideal, into a whip shape and manage the remaining buds.

In this study, as stated by Macit et al. (2017) and Toprak et al. (2018), a terminal bud was initially left in bud management, and the lateral buds at a distance of 7.5-12.5 cm just below were removed (Figure 3.5). According to the growth of the shoot, this work was done either without cutting the canopy, or if the canopy was cut, the uppermost bud was left as a new terminal. One reason for removing the terminal bush with canopy cutting is to reduce the tree's height. Therefore, cutting the head works best in late summer of the previous season to reduce the strength of the leader rather than in early spring.

Furthermore, as part of the bud management technique, after removing buds at intervals of 7.5-12.5 cm, the approach involved retaining one bud for every 2-5 removed buds. The objective was to establish a spiral arrangement of buds under and around the leader, commencing with the first bud just below it. This method results in the formation of a helical structure within the tree.

Figure 3.5 Uniform distribution of bud around the leader

For example, if the first lateral bud left is in the north direction, the next few buds can be removed, and a south-west oriented bud can be left. Again, after a few buds are removed from behind, a bud oriented to the east is selected. In other words, uniform distribution of buds around the leader is ensured in the final step of the process, at a height ranging from 30 to 45 cm above the ground; all lower buds beneath the last chosen bud were removed. The ultimate goal was to retain and nurture a bud that faced in a different direction every 7.5-12.5 cm under the leader (Figure 3.6). This method ensures the formation of a spiral-shaped arrangement of shoots during the bud selection and determination process.

Figure 3.6 Bud management practice in experiment

3.2.3 Bud Management +Perlan® Application

In the bud management + Perlan® application, the first step involved bud management, as described earlier. Following this, Perlan® was applied immediately. During the application of Perlan®, precautions were taken to ensure that it did not affect other nearby trees. These precautionary measures included covering the neighboring trees with plastic bags to prevent any unintended exposure to the Perlan® treatment.

3.2.4 Measurements and counts made on trees

- Tree diameter (mm): In all trees, the diameter of the tree was measured in November 2021, January 2023, 10 cm above the grafting point, using a 0.01 mm sensitive digital caliper (mm) (Figure 3.7).
- Tree height (cm): From the ground level of all trees to the top of the tree. Its length was measured in meters between November 2021 and January 2023.
- Number of shoots (number): The number of side shoots on the central leader and the number of primary shoots on the leader were measured in January 2023.

Figure 3.7 Measurement of the tree height,diameter and the diameter,length of the lateral shoots

- Shoot diameter (mm): The diameter of the primary shoots on the leader was measured 5 cm (mm) above the junction with the leader with a 0.01 mm sensitive caliper in January 2023.
- Shoot length (cm): The length of the primary shoots on the leader was measured in January 2023 with the help of meters from the junction with the leader.
- Canopy volume (m3) was calculated using the formula: Canopy volume (m3) = $\pi \times r^2 \times h / 3$ hhis formula measures the tree's radius (r) and canopy height (h) (Wocior, 2008). The calculation was carried out in May 2023.
- Tree volume (m^3): Tree volume with the formula = $[(L + W) / 4]\ 2.\pi.H / 2]$ tree height (H) and canopy length (L) were used and calculated by measuring in May 2023 (Stehr, 2005).
- New shoot formation rate of the existing buds (%).
- The number of lateral shoots emerging on the central leader

3.2.5 Statistical Analysis

The experiment was organized using a wholly randomized plot design, encompassing four treatments, including a control group. There were eight plots, each containing three trees, resulting in 96 nursery trees in the study.

To analyze the data, we employed analysis of variance (ANOVA) with the assistance of SPSS version 21.0. Additionally, “Duncan multiple range tests” were conducted to compare the means across treatments and determine significant differences.

4. RESULTS AND DISCUSSION

The tree height, tree diameter, and number of buds per tree were measured in 2021 after applying different treatments (Table 4.1). The different treatments were not significantly influence tree height and tree diameter. In contrast, the effect of different treatments on the number of buds per tree was significant.

The highest value of tree height (171.3 cm) was recorded in the Perlan® treatment, while the lowest value of tree height (151.1 cm) was observed in the control group. In tree trunk diameter, the thickest tree resulted from the Perlan® application (21.76 mm), whereas the lowest value of tree trunk diameter (20.42 mm) was noticed in the bud management treatment.

In the measurements made immediately after planting in this study, the number of buds per tree was found to be the highest in the Perlan® treatment (39.62), followed by the control group (34.25), the lowest value of the number of buds per tree (15.62) was noticed in the bud management treatment (Table 4.1). Since the bud counts are made after the bud removal in Perlan® and Bud management + Perlan® applications, it was seen that the trees were selected uniformly at the beginning, as can be seen when looking at the tree height and diameter.

Table 4.1 Tree height (cm), tree diameter (mm), and number of buds per tree of cherry tree in 2021

Treatments	Tree height (cm)	Tree trunk diameter (mm)	Number of buds per tree*
Control	151.1	20.66	34.25 a
Bud management	161.8	20.42	15.62 b
Perlan®	171.3	21.76	39.62 a
BM+P	167.1	21.04	16.29 b
Probability	NS	NS	P≤0.01**

*Buds were counted after bud removing in Perlan® and Bud management +Perlan® treatments.
NS: Non-significant. **Means followed by the same letter in the same column are not significantly different

The results at the end of the year (December) in 2022 on the effects of different treatments on the plant height (cm), tree trunk diameter (mm), and leader elongation (cm) of cherry trees indicated that the plant height and leader elongation was not significant, while the results for tree trunk diameter were significant (Table 4.2). The thickest trees were obtained from the Bud management + Perlan® treatment (32.64 mm) followed by (30.07 mm) in bud management treatments, while the trees of the control group were thinner (28.61) (Table 4.2). The tree height of the experiment varied between (222 cm) in the tree of Perlan® treatment and (237 cm) in the control tree group. Although not statistically significant, the most growth difference value was obtained in the control group's tree, whereas the lowest value was noticed (50.63 cm) in the Perlan® treatment trees.

Table 4.2 Tree height (cm), tree trunk diameter (mm), and leader elongation of cherry tree as influenced by different treatments in 2022

Treatments	Tree height (cm)	Tree trunk diameter (mm)	Leader elongation (cm)
Control	237	28.61 b	85.88
Bud management	235	30.07 ab	73.13
Perlan®	222	28.96 b	50.63
BM+P	230	32.64 a	62.88
Probability	NS	$P \leq 0.01$*	NS

NS: Non-significant. *Means followed by the same letter in the same column are not significantly different.

In this study, we measured the number, length, and diameter of shoots that had grown from buds, which were taken at the end of 2022 (December), as detailed in (Table 4.3). Notably, the highest number of shoots was observed in the Perlan® treatment. This finding aligns with the observations by Veinbrants and Miller (1981), who reported that Perlan® treatment increased the number of shoots from 4 to 11. Furthermore, research by Bennewitz et al. (2010) indicated that the total number of side shoots, in most cases, significantly increased in 'Stella' trees when a method similar to the one applied to 'Lapins' trees was used. Interestingly, the total shoot length and total side shoots were not affected by Promalin, the powder form of Perlan®, applications.

Additionally, it is worth mentioning that Jacyna et al. (1989) suggested that applying Promalin increased the number of shoots and fruiting short branches in cherry trees. The number of shoots in cherry trees is very important because they are “fruit production units” (Macit et al. 2017). For this reason, applications that increase the number of shoots in cherries are very important. Considering the data at the end of 2022 in this trial, the thinnest and shortest shoots were obtained from the Perlan® application (Table 4.3).

A statistically significant difference was observed among the treatments in terms of shoot diameter, length, and the number of shoots. The highest number of shoots, totaling 7.72, was recorded in trees subjected to the Perlan® treatment. This application was followed by BM+P (bud management + Perlan®) (6.91). The lowest values among the applications were obtained from control (2.58). The highest value of shoot length was observed in control plants (62.40 cm), followed by bud management treatments (49.89 cm). The lowest value was recorded in Perlan® treatments (41.11 cm). The maximum shoot diameter observed was (13.71 mm) in control trees, followed by (12.16 mm) in bud management treatments, while the minimum shoot diameter was recorded as (9.73 mm) in Perlan® treatment (Table 4.3). While the number of shoots decreases, the elongation and thickening of the existing shoots indicate a balance in growth. The limited growth resources in the plant move to the existing shoots, allowing them to develop. The more points the growth sources go to, the more shoots, and the less development there will be in those shoots. The fewer shots that go, the more development there will be in those shoots.

In fruit trees, moderately vigorous shoots are often preferred as they tend to be more conducive to productivity. Moderate shoots promote generative growth, essential for fruiting, whereas vigorous shoots encourage robust vegetative growth. Striking the right balance in shoot vigor is crucial for achieving a healthy balance between fruit production and vegetative growth in fruit trees.

Table 4.3 Number of shoots growth from buds, shoot length (cm), shoot diameter (mm) of cherry tree as influenced by different treatments in 2022 (December)

Treatments	Number of shoots growth from buds	Shoot length (cm)	Shoot diameter (mm)
Control	2.58 b	62.40 a	13.71 a
Bud management	5.16 b	49.89 ab	12.16 ab
Perlan®	7.72 a	41.11 b	9.73 b
BM+P	6.91 ab	40.04 b	10.39 b
Probability	P≤0.01*	P≤0.01*	P≤0.05*

*Means followed by the same letter in the same column are not significantly different

In the experiment there was statistically a significant difference among treatments in terms of the number of buds on the existing tree, as well as the number of newly formed shoots and the new shoot formation rate of the existing buds (Table 4.4). In the experiment, the highest number of shoot (7.72) was recorded in trees of Perlan® treatment followed by (6.91) in the tree of BM+P, the lowest number of shoot noticed in the control group and bud management treatment in which the buds were reduced by removing (Table 4.4).

Table 4.4 Number of newly formed shoots, numbers of shoots growth from buds and the new shoot formation rate of the existing buds

Treatments	Number of buds per tree	Number of shoots growth from buds	New shoot formation rate of the existing buds (%)
Control	34.25 a	2.58 b	7.85 c
Bud management	15.62 b	5.16 b	33.97 a
Perlan®	39.62 a	7.72 a	20.46 b
BM+ P	16.29 b	6.91 ab	44.33 a
Probability	P≤0.01*	P≤0.01*	P≤0.01*

*Means followed by the same letter in the same column are not significantly different

While the most new shoot formation was in the Perlan® treatment, followed by BM+P, the least was in the control and bud management treatments. Depending on these results, the rate of new shoot formation was highest in Perlan® and BM+P treatment, while it was the least in the control treatment. This must be because control trees with many buds did not have the power to grow them all. Because the growth resources are limited, as mentioned before, all parts of the plant and the existing buds compete to benefit from these resources. However, while the growth rate increased in plants with fewer buds, it increased even more in those encouraged to grow with Perlan® (Table 4.4).

In May 2023, The volume of the trees and specific canopy properties under examination were assessed, and the results are detailed in Table (4.5). Notably, there was a significant difference among the treatments concerning tree volume. Trees subjected to the bud management treatment exhibited the most substantial tree volume, measuring (1.40 m^3). This can be attributed to these trees' vigorous growth with fewer shoots. There were no significant differences among treatments in terms of tree height canopy height and canopy volume (Table 4.5). In the experiment, tree heights varied between (222 cm) and (237 cm), while canopy volume and heights varied between (0.40-0.80 cm^3) and (175.4-163.5 cm), respectively. In the experiment, Bud management + Perlan® caused smaller volume trees. Treatment including Perlan® decreased tree height and volume, increasing lateral shoots (Table 4.5).

Table 4.5 Tree height (cm), tree volume (m^3), canopy height (cm) and canopy volume (m^3), of cherry tree as influenced by different treatments in May 2023

	Tree		Canopy	
Treatments	**Height (cm)**	**Volume (cm^3)**	**Height (cm)**	**Volume (cm^3)**
Control	237	1.26 ab	175.4	0.80
Bud management	235	1.40 a	176.5	0.72
Perlan®	222	1.16 b	163.5	0.40
BM+P	230	1.11 b	0.52	0.52
Probability	NS	P≤0.05*	NS	NS

*Means followed by the same letter in the same column are not "significantly different. NS: Non significant"

Generally, Perlan® alone is known to stimulate the production of many side shoots, as documented by Veinbrants and Miller (1981). However, it is essential to note that Perlan® treatment tends to result in thinner and shorter shoots. On the other hand, bud management, when implemented in isolation, produces shoot that have the potential to develop into buds. However, the selective removal of some buds during this process can reduce the overall number of lateral shoots that subsequently emerge.

The results of different treatments obtained in the experiment were presented in Figure 4.1, 4.2, 4.3, 4.4. with the photographs taken at the same time.

Figure 4.1 The results of bud management treatment

Figure 4.2 The results of Perlan® treatment

Figure 4.3 The results of bud management + Perlan® treatment

Figure 4.4 The results of control treatment

The best results in the experiment were achieved through the combined bud management + Perlan® application. This approach led to more well-developed lateral shoots and promoted precocity, resulting in increased shoot numbers. Additionally, this application effectively controlled tree growth and tree volume. As a result, the simultaneous implementation of bud management and Perlan® proves to be highly advantageous for establishing a harmonious tree growth habit, encouraging the development of abundant lateral shoots, and promoting early fruiting in cherry nursery trees.

It is important to emphasize that further research is required to determine the optimal Perlan® dosage and fine-tune the details of the bud management system in order to attain the desired tree form and overall tree performance.

5. CONCLUSION AND RECOMMENDATIONS

In modern global cherry cultivation, there are critical practices and methods such as bending, tipping, branch training, and Perlan® applications that might appear straightforward but hold paramount importance for the trees. These aspects necessitate in-depth exploration to enhance the quality of cultivation. Moreover, these practices accelerate tree growth within their allocated garden space, leading to early fruit-bearing canopies.

Consequently, recent research was concentrated on compact planting training systems for cherries. The primary goal is to foster lateral branch development within these systems through meticulous branch training, Perlan® applications, or a combination of both. Rather than mere cutting and pruning, meticulous branch management involving cuttings can lead to improved yield and quality. This approach ensures consistent nutrient distribution, produces remarkable and high-quality fruits, enables uniform light exposure for branches, and simplifies overall cultural processes.

The outcomes of this study demonstrate that applying meticulous branch management alongside Perlan® results in early fruiting of cherry seedlings, moderate tree growth, and abundant lateral growth. These findings prove highly beneficial in terms of establishing healthy cherry orchards.

Nevertheless, further research is required to pinpoint optimal Perlan® dosages and attain ideal tree formation through meticulous branch management. Sustaining research efforts in this field will not only directly impact cherry production in producing countries but also make substantial contributions to their economies.

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CURRICULUM VITEA

Ahmed MOUSA bachelor's degree in Horticulture Department, Agriculture Faculty, Babylon University, in 2010. Topic: " The effect of temperature on the potato crop in Iraq".

Languages

Arabic Native, English C1,

Computer Skills

SPSS, MS Office.

Contact Information :

ORCID ID : 0009-0007-6200-2035

Publications :

1. Mousa, A.A., Soysal, D., Demirsoy, H., (2022). Controlling of the growth and development of lateral shoots in sweet cherry trees. 8th International Agriculture and Natural Sciences Congress. Ankara, Türkiye.