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Research Article

Systematic reviews of self-pruning incidents on commercial horticulture plants

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ABSTRACT

Pruning is a crucial practice in horticulture to maintain tree health, reduce production costs, and improve yield. However, conventional pruning remains labor-intensive and costly. Self-pruning has the potential to provide a sustainable alternative, yet studies on its mechanisms and applications in horticultural crops are still limited. This review aimed to systematically synthesize the mechanisms, incidence, and potential applications of self-pruning in horticultural crops. The review followed the PRISMA 2020 framework to ensure transparency and minimize bias. Literature searches were conducted in ScienceDirect and Garuda databases using the keywords self-pruning, pruning, cladoptosis, autophagy, and senescence in both English and Indonesian. The search was restricted to articles published within the last 10 years (2013–2022). Inclusion criteria were original research or review articles on self-pruning in plants. Exclusion criteria were duplicate records, articles from irrelevant fields, non-systematic studies, and grey literature. Bias reduction was addressed by predefined criteria, time limits, specific keywords, and independent screening by two reviewers. From 5,588 records identified, only 25 articles met the inclusion criteria. However, none of the eligible studies specifically addressed self-pruning in horticultural crops. The limited number of relevant articles was due to restricted database coverage and the absence of standardized quality assessment tools within the PRISMA framework. This review highlights a critical research gap on self-pruning in horticultural crops. Broader database searches and the development of standardized quality assessment tools are required. Evaluating the incidence and mechanisms of self-pruning in commercial horticultural crops is essential as a new perspective to support sustainable horticultural production.

Keywords: autophagy; abscission; cladoptosis; programmed cell death; senescence

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INTRODUCTION

Horticultural crops, especially fruit trees, are important commodities as a source of food, minerals, and health, and also play an important role in economic and ecological sustainability (Harris et al., 2022). Globally, there are hundreds of cultivated species of fruit trees, and at least 39 species of them are commercially traded (https://www.statista.com). A fruit tree is defined as a woody fruit plant (Santosa et al., 2021).

Pruning is a routine maintenance activity in horticulture management of both nursery and production fields, especially in fruit tree species (Stiles, 1984). In recent times, fruit tree species have also become popular as city greenery (Herianti et al., 2022; Ruwaida et al., 2022; Santosa et al., 2021; Saputro et al., 2022), and tree pruning is also part of safety. Pruning reduces the plant canopy manually or mechanically by cutting unwanted branches and twigs to form an optimal architecture and maintain the balance of a sink-source (Karkee et al., 2014; Kolmanič et al., 2021; Yuliana et al., 2017). Canopy pruning shapes effective light interception, forms strong branches, manages canopy moisture, suppresses pest and disease infections, and facilitates tree activities such as fertilizer application and harvesting (Nath & Kumar, 2013; Yuliana et al., 2017), beauty and safety (Herianti et al., 2022; Ruwaida et al., 2022; Saputro et al., 2022). Pruning also reduces the impact of alternate bearings, removes negative branches, improves fruit quality and quantity, regulates the allocation and distribution of photosynthate, and maintains tree health (Budiarto et al., 2019b). For example, pruning in citrus stimulates the growth of new shoots and leaves, increases the number of flowers by 85%, fruit set by 76%, and fruit weight (Budiarto et al., 2019a; Septirosya et al., 2017; Sugiyatno et al., 2019). Here, root pruning is not included. See Budiarto et al. (2019b) for root pruning terminology.

Nevertheless, irrespective of the region, pruning is costly because it requires skills, labor allocation, time, and fuel (Gokavi et al., 2021; Martin-Gorriz et al., 2021; Rismarini, 2012; Saragih et al., 2020). For example, pruning citrus trees in South Kalimantan, Indonesia, costs around 24% of the total maintenance costs (Rismarini, 2012). Pruning cost depends on location, it varies from 4.5 million rupiahs (about USD 375) in Indonesia (Saragih et al., 2020) and €810 per ha per year in the temperate zone (Martin-Gorriz et al., 2021). Therefore, in order to develop competitive and more affordable horticulture products, improvement in pruning technology is greatly important. There have been many attempts to reduce the cost of pruning, including mechanization and automation (Karkee et al., 2014; Kolmanič et al., 2021). However, the results are still unsatisfactory in terms of yield, production quality, and cost reduction (Karkee et al., 2014). Therefore, horticulture technology improvement in terms of cost efficiency and environmental friendliness is required.

Self-pruning can be an alternative technology to build ideal tree canopy architecture with low inputs (Paisey et al., 2022). Self-pruning is a phenomenon of branch abscission, and the terminology was introduced in the 1920s (Millington & Chaney, 1973). According to Bhat et al. (1986), self-pruning affects tree growth and development, and the formation of the tree canopy. Nevertheless, studies on self-pruning are still limited. Genetic regulation significantly influences the self-pruning mechanism in plants. In citrus, this process is critical for initiating flower buds. Transcriptomic profiling via microarray during three self-pruning stages identified 1,378 differentially expressed genes, including four genes involved in the synthesis and metabolism of abscisic acid (Zhang et al., 2014). In *Vitis vinifera*, transcript analysis through RNA-seq and qPCR revealed that *ACO1* enhances ethylene release and downregulates auxin transport in the abscission zone (Zou et al. 2020). In tomato, Anthirrinum, and Arabidopsis, there are genes involved in self-pruning, such as the *self-pruning gene* (SP gene), *Centroradialis gene* (CEN), and *Terminal Flower1* (TFL1) (Pnueli et al. 1998; Si et al. 2018). However, research on self-pruning that occurs in the branching of woody horticultural plants is very limited. The review aimed to critically examine the mechanisms and incidence of self-pruning and its potential applications in horticultural crops.

MATERIALS AND METHODS

The study was carried out from January to December 2022. The method used was "Preferred Reporting Items for Systematic Reviews and Meta-Analytic [PRISMA]" (https://estech.shinyapps.io/prisma_flowdiagram), a software application based on the web (Santosa et al., 2021). All articles that have passed the selection process were then reviewed and summarized. The articles were obtained from publications available on the ScienceDirect (www.sciencedirect.com) and Garuda (www.garuda.com). The Garuda is a scientific portal maintained by the Indonesian Government that compiles all Indonesian journals.

The study followed five stages. Initially, articles were collected by using keywords: self-pruning, pruning, cladoptosis, autophagy, and senescence in both English and Indonesian. The total count was calculated from the number of articles that appeared, including the articles on websites that did not have PDFs. Sciencedirect handles a huge number of journals with very diverse subjects, resulting in a huge number of less relevant articles even after refined searching. For example, the keyword of 'self-pruning' in the ScienceDirect platform spreads over 10 areas of subjects, including mathematics and computer science; here, only three relevant subjects were considered, i.e., Agricultural and Biological Sciences, Environmental Science, and Biochemistry, Genetics, and Molecular Biology. In the case of the Google platform, the total count was designed based on the first 16 pages by excluding simple definitions as irrelevant articles.

Secondly, the articles were evaluated for their relevance to the subject of 'tree or crop' based on matching words available in the abstract or keywords. In this step, articles related to other subjects, such as mammals, electronics, computers, mathematics, and physics, were excluded and classified as irrelevant. Thirdly, relevant articles were then screened further by reading the abstract or full article. Here, the articles were selected strictly, only those related to self-pruning by the author's judgment.

Fourthly, article duplication was eliminated. The duplication was identified from the title or its translation in case the original title was not written in English. In the final screening, all full articles were downloaded and read carefully. There are 5249 articles from the database. Basic information, including date of publication, subject and aspect, species, and all keywords, was collected for mapping.

Since the characteristics of each platform were very different. The Sciencedirect provided a refined searching feature, while on Garuda, such a feature was not available. Thus, the accuracy of the review could be affected by these features.

RESULTS

Publication related to self-pruning

The systematic review demonstrated that there were currently no published studies specifically addressing natural self-pruning in horticultural crops (Figure 1). Existing literature focuses either on forestry species or on molecular and physiological mechanisms in model plants, rather than on fruit-bearing crops. This finding highlights a substantial research gap in understanding self-pruning as a potential low-input pruning strategy for horticultural production.

From references, the definition of self-pruning in plant biology is clear; however, caution is needed because similar terminology is also found in computer science (Yun & Oh, 2007). Self-pruning or cladoptosis is the abscission of a branch independently, irrespective of slow and rapid shedding. According to Bhat et al. (1986), self-pruning includes the senescence of branches, branchlets, and twigs. To some extent, factors contributing to self-pruning incidents were clearly defined, such as morphology, physiology, genetics, and environment (Kint et al., 2010). Moreover, Kint et al. (2010) developed self-pruning modeling and concluded that processes contributing to self-pruning include the tree stage of development, level of competition, tree density, and relative humidity.

A total of 5,588 articles were initially retrieved (5,249 from ScienceDirect and 339 from Garuda). Of these, 1,515 were excluded for not being related to the fields of agriculture, environmental science, or biology. A further 938 duplicate articles were removed, followed by the exclusion of 623 articles that were neither review papers nor original research. This left 2,512 articles for further screening. Of these, 2,405 were excluded for not being related to plant sciences, leaving 107 articles. After applying the definition of self-pruning, 82 articles were excluded, and 25 articles remained. However, none of these addressed natural pruning autonomously performed by plants themselves in horticultural crops.

In the Garuda platform, self-pruning was identified as pruning (*pemangkasan* in Indonesian), and exploration found 98 articles in the first stage. When viewed, its relevance to tree or crop also showed a number of 47 articles, but when cross-checked with the definition of self-pruning, none were relevant. Most of the available articles described the technical application of pruning in various crops; therefore, the number of relevant articles was zero.

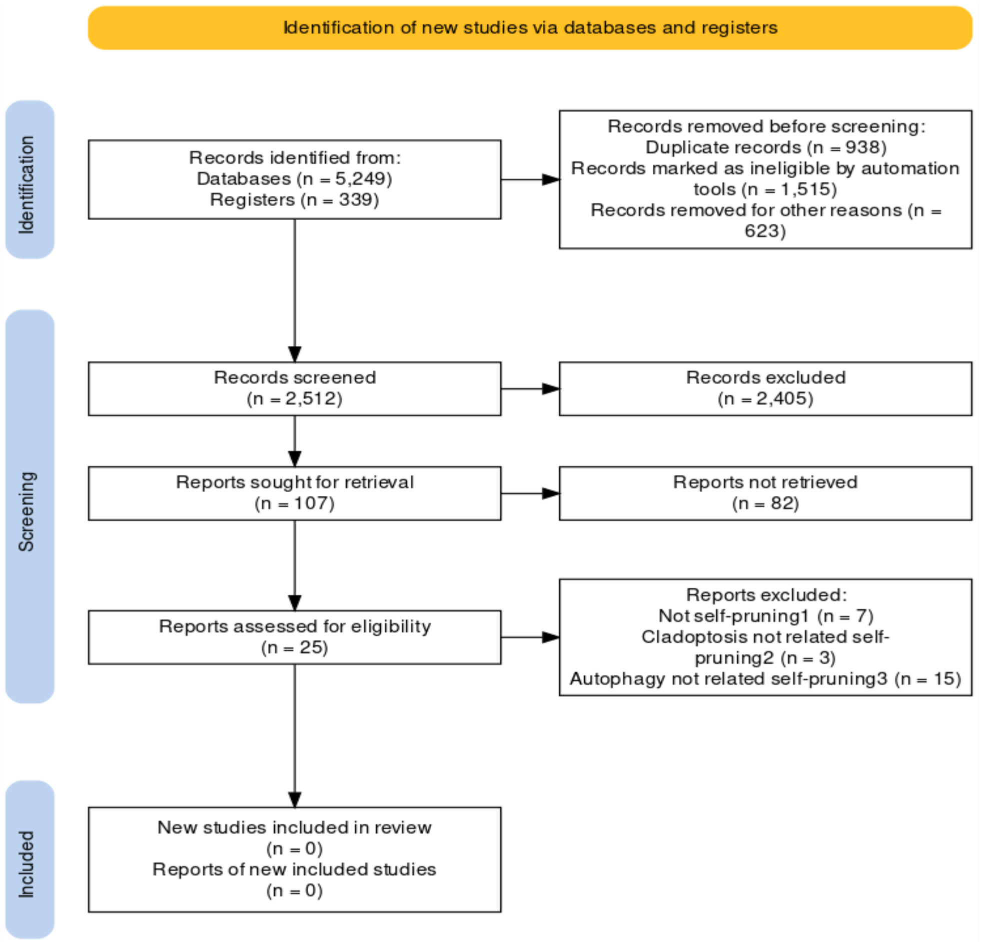

Figure 1. PRISMA Flow diagram with keywords self-pruning, pruning, cladoptosis, and autophagy on Scincedirect and Garuda databases

On the other hand, ScienceDirect and Google mostly showed many articles relevant to self-pruning in the forestry subject, and only a few on horticultural crops (Figure 1). The lack of information on horticultural crops might be because the self-pruning phenomenon had not been a concern for horticulture scientists. Thus, this report is the first review of the potential application of self-pruning in horticulture crops.

The absence of studies specifically addressing self-pruning in horticultural crops highlights a significant research gap. While self-pruning had been described in forestry and model plants, it had not been systematically explored as a natural mechanism in fruit crops, despite its potential relevance for reducing pruning costs and improving canopy management. This suggests that horticultural research has prioritized manual or mechanized pruning techniques over biological mechanisms of pruning.

Although PRISMA was applied to ensure transparency in the review process, this study has several limitations. First, PRISMA does not evaluate the methodological quality or risk of bias of the included studies. Second, the comprehensiveness of the results was limited by the choice of only two databases (ScienceDirect and Garuda), potentially excluding relevant articles indexed in PubMed, Scopus, or Web of Science. Third, the search strategy was constrained by the use of predefined keywords and a 10-year publication, which may have overlooked relevant studies outside this scope. Finally, the heterogeneity and limited number of available studies reduce the strength of conclusions regarding self-pruning in horticultural crops.

DISCUSSION

The results of this systematic review confirm the absence of studies specifically investigating natural self-pruning in horticultural crops. This research gap is notable, as self-pruning could potentially serve as a biological alternative to conventional pruning methods, offering a low-input and sustainable approach to canopy management. Instead, available studies have concentrated on forestry species or model plants, where self-pruning has been associated with morphological, physiological, genetic, and environmental factors. These insights, however, remain underutilized in the context of fruit-bearing crops.

One possible explanation for this gap is the research focus of horticultural scientists, who may have prioritized practical and technical aspects of manual or mechanized pruning to support immediate productivity, rather than exploring natural plant mechanisms. The reliance on labor-intensive pruning methods continues to impose high costs on commercial horticultural production, underscoring the importance of developing alternative strategies. Self-pruning, if better understood, could reduce dependency on costly practices while contributing to more sustainable production systems.

The present study, however, has several limitations that must be acknowledged. The restriction to only two databases (ScienceDirect and Garuda) may have overlooked potentially relevant publications indexed elsewhere, such as PubMed, Scopus, or Web of Science. Furthermore, the 10-year time frame and reliance on predefined keywords may have excluded studies with alternative terminology or older yet still relevant findings. Importantly, while PRISMA ensured transparency in the selection process, it does not provide tools for assessing methodological quality, which may have limited the robustness of the conclusions.

Despite these limitations, this review highlights the importance of further investigation into self-pruning in horticultural crops. Future research should expand database coverage, adopt broader search strategies, and employ quality assessment tools to ensure reliability. At the same time, molecular, physiological, and genetic mechanisms underlying self-pruning in model plants and forestry species should be adapted and tested in fruit crops. Such studies would provide the foundation for integrating self-pruning as a cost-effective and environmentally friendly strategy in sustainable horticulture. However, several points can be drawn from the results of the literature review as follows.

Systemic self-pruning

Self-pruning occurs systemically or spontaneously with internal and external inducers. Systemic self-pruning takes place gradually and is determined by branch morphology, pest and disease infection, age, nutritional balance, and environmental stress (Burrows et al. 2007; de Ollas et al., 2012; Kono et al., 2019; Miyakawa et al., 2013; Pierre-Eric, 2009).

The joining morphology of branch and stem is the cause of the self-pruning in *Wollemia nobilis* (Araucariaceae) as described by Burrows et al. (2007); namely, the emergence of branch-base xylem constriction due to the growth of new branches that push the previous branches to fall. This is different from self-pruning due to the age of the branches. According to Kono et al. (2019), branch abscission due to age is a consequence of non-structural carbon starvation due to phloem transport failure following the hydraulic failure and reduced respiration.

Dead and branch abscission due to pests and diseases has become a common phenomenon in many plants. According to Matheny and Clark (1994), disease and pest attacks encourage localized decay. Given these facts, there is certainly not much controversy. Branch abscission due to physiological imbalances is still challenging, but it is common that physiological imbalances become stimulators in the abscisic process of leaves, flowers, fruits, and branches (Kono et al., 2019; Zhang et al., 2009). Zhang et al. (2009) stated that senescent branchlets in *C. equisetifolia* correlate with higher protein-bound condensed tannins (PBCT), lower N content, and higher total condensed tannins (TCT): N ratio.

Environmental stresses such as shade, drought, flooding, extreme temperatures, and pest and disease attack induce systemic self-pruning (Bellani & Bottacci, 1995; Kozlowski, 1973; Miyakawa et al., 2013). Environmental stress will increase the concentration of certain hormones that trigger the senescence process (de Ollas et al., 2012; Miyakawa et al., 2013; Pierre-Eric, 2009). The duration of the process from stress induction to the occurrence of self-pruning in branches has not been widely studied. This is in contrast to abscission in fruit, which is a relatively fast response as shown by growth inhibition and fruit fall (García-Sánchez et al., 2007).

Plant hormone activity is modulated by environmental factors and induced stress conditions such as drought. In general, drought—particularly under severe conditions—alters hormonal levels across various plant systems, either increasing or decreasing concentrations depending on the specific hormone involved. For example, abscisic acid levels in both leaves and roots rose significantly under intense drought stress in Valencia orange (VO) and Tahiti acid lime (TAL), when grafted onto two orange rootstocks: Rangpur lime (RL) and Sunki Maravilha mandarin (SM) (Santana-Vieira et al., 2016). Similarly, findings by de Ollas et al. (2012) on drought-stressed citrus plants demonstrated elevated levels of abscisic acid and jasmonic acid accumulation during periods of extreme water deficiency. Notably, the increased concentration of abscisic acid is associated with the activation of self-pruning mechanisms.

Spontaneous self-pruning

Spontaneous self-pruning due to physical stress associated with the branch structure. The weak structure of the branch causes branches to fail to withstand loads from wind, water/ice loads, and fruit set loads. Sometimes, the combination of a weak structure, disease, and pest attack accelerates branch shedding (Matheny & Clark 1994). According to Slater (2021), branches without bulging or having small bulges easily detach spontaneously. According to Farrell (2003), weak crotch strength makes branches easy to loosen; the presence of crotch strength is determined by the tree species, diameter ratio, branch inside-bark diameter/crotch width, branch inside-bark diameter, trunk diameter/crotch width, rough branch diameter/crotch width, and branch angle. Kint et al. (2010) noted that the dying of branches is determined by their position and dimension, including branch diameter and branch insertion angle.

Apart from the branch structure, spontaneous self-pruning is in some cases associated with the hydraulic failure of the tree architecture. According to Cruiziat et al. (2002), the concept of hydraulic tree architecture analogizes the existence of a collection of water pipes incorporated in a hydraulic system that connects root flow, xylem network, and transpiration. The assessment of the hydraulic failure of plant species concerning the environment often uses the Huber value approach, namely, it measures the carbon storage on the stem per unit leaf area (Kono et al., 2019; Wang, 2005).

Huber value (HV) is obtained from the ratio of the area of the sapwood cross-section or stem cross-section (mm^2 or m^2) divided by the distal leaf area (m^2) attached to the stem (Wang, 2005). HV is also applicable for total leaf dry weight (g) (Cruiziat et al., 2002). Thus, the HV unit could be in mm^2m^{-2} or m^2m^{-2} or $mm^2\ g^{-1}$. HV varies in woody evergreen (>0.0004) and deciduous (<0.0004) (Wang, 2005). According to Cruiziat et al. (2002), the HV of sun leaves is larger than shade leaves of a tree; and varies within a species growing in different climates, e.g., HV temperate climates 0.5 $mm^2\ g^{-1}$, HV humid or shaded sites 0.2 $mm^2\ g^{-1}$, and HV tree growing in the dry and sunny environment is 5.9 $mm^2\ g^{-1}$. However, HV profiles of horticulture crops are still rare.

Self-pruning, programmed cell death, and gene control

In general, organ death, such as the whole branch, is the final form of the process of individual systemic cell death that occurs massively. The process of programmed cell death is called programmed cell death (PCD) to control cell numbers, remove unwanted diseased or damaged cells, and maintain cellular homeostasis (Ambastha et al., 2015). Of course, not all individual cell deaths will end in organ death.

In animal cells, PCD in general is distinguished as apoptosis (type I PCD), autophagy (type II PCD), and necrosis (Kroemer et al., 2009). In plants, PCD is initially distinguished into autolytic and non-autolytic PCD (van Doorn, 2011). van Doorn (2011) explained that autolytic rapid clearing of the cell due to hydrolases released from the vacuole, while non-autolytic (not accompanied by rapid clearance of the cytoplasm) is found in cases of hypersensitive response and necrotrophic plant pathogens.

Understanding the PCD mechanism can be an entry point for manipulating self-pruning in horticulture crops. PCD induction in plants can be divided into two, i.e., biotic stress of pathogens (pathogen-related PCD) and non-biotic stress, as well as during normal development (developmental PCD) (van Doorn & Papini, 2013). Cell death due to necrosis is not considered because it is generally a chaotic and uncontrolled cell death. Here, the authors follow the view that PCD in plants is autophagic (type II PCD) after Bozhkov and Jansson (2007) and Qi et al. (2021). Indeed, the presence of type I and type II PCD can occur simultaneously in a single case, such as the infection with the pathogen Sclerotinia sclerotiorum using oxalic acid (Kabbage et al., 2013).

Autophagy (type II PCD) is a catabolic process in which cytoplasmic components, such as proteins and organelles, are degraded in the lysosomes or vacuoles for recycling (Yang et al., 2020). In case of organ death, cell substances are degraded to sucrose, amino acids, and amides and transported to other organs (Chen et al., 2019; Gregersen et al., 2008; Reid, 2012; van Doorn, 2004; van Doorn, 2011). Autophagy is key to function in senescence, root meristem maintenance, nutrient recycling, starch degradation, and plant immunity (Qi et al., 2021; Yang et al., 2020).

The autophagy phenomenon might be explored to obtain benefits in horticulture, because it improves plant performance through nutrient allocation, nutrient remobilization, and plant immunity (Bozhkov, 2018; Qi et al., 2021; Yang et al., 2020). To support this idea, Bozhkov (2018) recommends studying several factors to gain the benefit of autophagy, such as key nutrients involved in autophagy, directing autophagy to certain organs, promoting selective autophagy, and selecting chemicals that are able to promote specific autophagy. In general, several agronomic factors are known to activate autophagy such as stress low light intensity (darkness) (Yang et al., 2020), nitrogen starvation (Ren et al., 2014), salt and osmotic stress, heat stress, and hypoxia (Qi et al., 2021), abiotic stresses, and hormones (Xia et al., 2011), and biotic stress (van Breusegem & Dat, 2006; Xing et al., 2013).

In recent understanding, autophagy in plants occurs at levels of micro-autophagy, macro-autophagy, and mega-autophagy involving AuTophaGy-related (ATG) genes (van Doorn & Papini, 2013). ATG genes are transcriptionally regulated, and more than 30 ATG genes are responsible for the autophagy process in plant adaptations to environmental stresses (Marshall & Vierstra, 2018; Qi et al., 2021). During organ senescence, the expression of ATG genes increases (Avila-Ospina et al., 2016). On the other hand, mega-autophagy is unlikely to involve any genes (Wang et al., 2021). Thus, mega-autophagy or massive autophagy, or autolysis (van Doorn & Papini, 2013; Wang et al., 2021) still needs more study, especially in horticulture crops.

Future perspectives

Reports on self-pruning in horticulture crops are still scarce (Table 1). According to Zhang et al. (2014), the apical meristem, measuring 0.5-2.0 cm long in *Citrus sinensis*, underwent senescence. Here, we consider that the shoot meristem senescence can be considered as a minor self-pruning. The case of minor self-pruning occurred in tomato, orange, apple, cotton, and grape plants (Table 1). Citrus plants experience minor self-pruning when exposed to drought and inundation, and are treated with ethylene and abscisic acid (Argamasilla et al., 2014; Vives-Peris et al., 2017). According to Gómez-Cadenas et al. (1996), drought induces and increases the abscisic acid (ABA) content in citrus roots, followed by an increase in amino cyclopropane carboxylate (ACC), and transports it to the leaves, causing leaf abscission. It is well known that the biosynthesis of ethylene and abscisic acid is influenced by genes (Goldental-Cohen et al., 2017; Zhang et al., 2014), where genes are upregulated due to stress induction and application of exogenous hormones (John-Karuppiah & Burns, 2010).

Table 1. Some horticulture species that show occurrences of self-pruning

Species	Cell or organ studied	Study design	Main finding	References
Apple (*Malus domestica*)	Meristem apical, bunga	Transcriptomic and physiological studies	Identified genes related to floral induction and regulation of self-pruning	(Botton et al., 2011; Eccher et al., 2013)
Grapes (*Vitis vinifera*)	Meristem	RNA-seq and qPCR	ACO1 promotes ethylene biosynthesis and downregulates auxin transport in abscission zone	(Zou et al., 2020)
Orange (*Citrus sinensis*)	Spring shoot tip	Microarray analysis	Identified 1,378 differentially expressed genes; ABA-related genes involved in self-pruning	(Zhang et al., 2014)
Tomato (*Solanum lycopersicum*)	Meristem apical, axillary shoot	Genetic and molecular (mutants, transgenic studies)	SP, CEN, and TFL1 genes regulate growth termination and branching	(Komochi, 1965; Pnueli et al., 1998; Carmel-Goren et al., 2003; Silva et al., 2018)
Pecan (*Carya illinoinensis*)	Branch	Field observation	Natural self-pruning observed in branch abscission, influencing canopy formation	(Reid, 2012)

Self-pruning, both autophagic and spontaneous abscissions, has the potential to support cost-effective pruning technologies. The benefit will replace conventional pruning techniques, which rely on labor-intensive and machinery (Karkee et al., 2014; Kolmanič et al., 2021). In tomatoes, self-pruning is an inherited character (Komochi, 1965). From the scientific perspective, self-pruning is a new term in horticulture. Since plant autophagy could be an essential factor in self-pruning, irrespective of the internal and external inducers, connecting fundamental facts about autophagy is promising for crop improvement, as stated by Bozhkov (2018).

For such purposes, it is interesting to study fundamental aspects of plant cell biology, metabolism, molecular, and morphological characteristics that trigger autophagy as well as spontaneous abscission. Determining model plants undergoing self-pruning is important; in this case, horticulture crops such as tomatoes, citrus, grapes, and apples could be interesting subjects. Secondly, it is necessary to study morphology, structural strength of branches, and the physiological and molecular mechanisms associated with the induction of controlled autophagy. Thirdly, manipulating horticulture technology to disrupt the balance of nutrients, nutrient management, hormones, and environmental factors such as shade and water availability could be a priority in horticulture to target self-pruning in certain branches. According to Guiboileau et al. (2013), carbon and nitrogen metabolism could play a central role in autophagy. Finally, a study on environmental pressure, such as wind speed, could be applicable in the promotion of spontaneous abscission.

The potential of self-pruning in horticultural pruning, especially in fruit crops

In perennial horticultural systems, pruning is a critical practice used to sustain yield, maintain the balance between vegetative and reproductive growth, and enhance fruit quality. Nevertheless, conventional pruning methods involve substantial labor costs. Naturally, plants undergo organ abscission—such as the shedding of leaves, fruits, or flowers—when these organs mature or become redundant. Self-pruning, a specific form of abscission that occurs at the shoot apex, has been documented in species like citrus, chestnut, and tomato (Jiang et al., 2008; Paisey et al., 2022; Plummer et al., 1991; Zhang et al., 2014).

Self-pruning has the potential to serve as a biological substitute for manual or mechanical pruning. According to Zhang et al. (2014), programmed cell death (PCD) in citrus takes place in a systematic and progressive manner and is likely involved in regulating self-pruning. Microarray analysis examining gene expression during three stages of self-pruning identified 1,378 differentially expressed genes. These included genes related to PCD as well as those associated with cell wall biosynthesis and metabolism. The findings suggest that during self-pruning, the abscission layer activates both degradative (catabolic) and constructive (anabolic) pathways for cell wall remodeling. Moreover, a strong relationship was observed between self-pruning events and the expression of hormone-responsive genes. In citrus, self-pruning contributes significantly to the initiation of floral buds, supporting the notion that one of the physiological functions of pruning is to stimulate flowering. This phenomenon is also evident in grapevines, where the application of self-pruning mechanisms could enhance production efficiency by reducing reliance on manual pruning. Similar to other forms of abscission, self-pruning requires the development of a specialized abscission zone (AZ) (Plummer et al., 1991). The hormonal balance within the plant is a key regulator of this process: ethylene promotes the formation of the AZ, while auxin acts as an inhibitor. A reduction in auxin levels enhances the plant's sensitivity to ethylene, thereby facilitating AZ differentiation (Agustí et al., 2008; Mishra et al., 2008; Pattison et al., 2012).

During abscission, ethylene increases the expression of an ACC oxidase (ACO) gene and the activity of ACO while inhibiting the transportation of auxin. In the current study, the expression of the ACO1 gene was found to increase during self-pruning in the autotetraploid grape vine shoot tip. Based on several feeding research results, it can be mentioned that self-pruning has the potential to replace manual and mechanical pruning if further developed.

Self-pruning on herbaceous vegetables, ornamental, and medical plants.

Self-pruning in herbaceous vegetables usually takes the form of abscission and senescence; these processes are also included in self-pruning. Self-pruning that occurs is basically the same as horticultural plants, especially fruit plants, in herbaceous vegetables, ornamental plants, and medical plants. Self-pruning occurs in leaves, flowers, and fruits. The occurrence of this event is influenced by the hormone ethylene. This is because ethylene functions within the network, namely, accelerating the expansion of flowers, the ripening of fruit, the formation of the abscission layer of petioles, and the growth of roots. Consequently, its function in adaptation is to facilitate growth and accelerate maturation, thereby reducing the life cycle (Adnyana, 2014). The role of ethylene in self-pruning in flowering plants was investigated by van Doorn (2004), who demonstrated that orchid petals are highly sensitive to this hormone, leading to abscission. Furthermore, ethylene and auxin plant hormones have been identified as key regulators of tomato organ abscission, inducing and inhibiting this process (Bar-Dror et al., 2011).

The regulation of leaf abscission is closely influenced by the dynamic interplay between auxin and ethylene. While ethylene serves as the principal hormonal regulator of this process, its effect is largely dependent on the auxin concentration within the leaf. The antagonistic interaction between these two hormones is particularly evident in the abscission zone, where auxin levels modulate cellular sensitivity to ethylene. Therefore, a tightly maintained hormonal balance between auxin and ethylene is essential for the proper control of leaf abscission. During the process of senescence, leaves exhibit a reduction in auxin production (van Doorn, 2004). Leaf senescence begins at the molecular level after the leaf has fully expanded. At this point, various biological processes are activated while others are downregulated or cease entirely. The progression of leaf senescence is typically categorized into three distinct phases. The initial phase, known as the initiation stage, can be triggered by hormonal signals or environmental cues, age, or pathogens. At the physiological level, metabolic thresholds are crossed, redox states are altered, and signalling cascades are activated. The second phase can be influenced by hormones and the environment. During this stage, leaf cells reorganise to respond to the process of degeneration. This is achieved by the activation of wild pathways, a shift in metabolism from autotrophic to heterotrophic, detoxification, and the reversible organelles (Ferrante & Francini, 2006).

The process of self-pruning in herbaceous vegetables and ornamental plants can occur naturally or as a result of the induction of exogenous hormones. The sensitivity of ornamental plants to exogenous ethylene was investigated through the exposure of the plants to 0-15 µL L^{-1} ethylene for 24 or 72 hours in darkness at 20 °C. The findings indicated that ornamental plants in the flowering stage were typically more susceptible to ethylene treatment than those in the foliage stage. Nevertheless, the effects of ethylene were observed as a lack of flowers, flower buds, or intact inflorescences after 24 hours. In the case of foliage plants, abscission and yellowing of leaves were noted after 72 hours. Symptoms of ethylene toxicity have been described, and 52 species have been classified according to their ethylene sensitivity (Ferrante & Francini, 2006).

The cultivation of mustard plants in soil with an optimal nitrogen concentration (80 mg N per kg soil) and the application of 200 µL L^{-1} ethephon resulted in optimal ethylene production, the greatest stomatal conductance and photosynthesis, and the best growth (Iqbal et al., 2011). In 2005 and 2007, ethephon (0-400 mg L^{-1}) was applied to Redhaven peach trees 45-50 days after full bloom to induce fruit abscission. It was determined that the rate of abscission was directly proportional to the concentration of ethephon, resulting in a reduction of the fruit yield by 70% to 100%. The application of ethephon at a concentration range of 100-200 mg L^{-1} was found to effectively induce abscission in Red Haven peach fruit, while simultaneously preventing the occurrence of stem or limb gummosis (Taheri et al., 2012). The application of 400 ppm, 600 ppm, and 700 ppm to lemon fruit abscission did not yield a statistically significant outcome. However, a 23% reduction in the dataset was observed following the application of 600 ppm ethephon (Torregrosa et al., 2010).

CONCLUSIONS

This systematic review revealed no reports of naturally occurring self-pruning in fruit-bearing horticultural crops. Current literature mainly focuses on forestry species and model plants, with limited molecular, physiological, and genetic insights that cannot yet be translated into practical horticultural applications. The absence of eligible studies underscores a major research gap and indicates that self-pruning has not been adequately addressed within horticultural science. Several limitations of this review should be acknowledged. The search was restricted to only two databases (ScienceDirect and Garuda), applied predefined keywords, and covered only 10 years, potentially excluding relevant articles. Additionally, the PRISMA framework employed does not assess methodological quality, which may affect the reliability of conclusions. Future research should adopt broader search strategies across multiple databases and apply standardized quality assessment tools. Studies should specifically investigate self-pruning incidents in fruit crops, focusing on canopy regulation, branch abscission, and stress-induced mechanisms. At the molecular and physiological levels, emphasis should be placed on hormonal regulation, autophagy-related genes, and programmed cell death pathways. Combining these with field-level experiments will provide a more comprehensive understanding of how self-pruning can be harnessed. Advancing this knowledge is essential for evaluating self-pruning as a cost-effective, environmentally friendly alternative to conventional pruning practices, with potential to reduce labor costs, improve canopy management, and enhance sustainability in horticultural production.

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