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# Weed Management Practices in Nursery Propagation

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## Abstract

Weeds are inimical to the nursery growers as they negatively interfere with the growth and aesthetic value of nursery crops. Propagated crops are more vulnerable to weed competition. Nursery growers are adopting hand weeding, mulching, and different herbicides to get rid of the weeds in propagation. However, the most effective and efficient methods for weed control in propagation are still obscure. In this study, we comprehensively review the most used propagation techniques and weed management practices along with their pros and cons. Hand weeding is the most common method of weed control, but it is labor intensive and costly. Nowadays, herbicides are widely used for weeds management. But there are a limited number of registered and labelled herbicides for greenhouse use. Most of the herbicides contain dinitroanilines (DNAs) which inhibit root growth. Along with the leaching problem, several detrimental effects of herbicides have been revealed in propagation. Considering drawbacks of the use of herbicides, mulching in propagation is gaining popularity. But mulch type and depth may affect rooting of cuttings and weed control efficacy. Therefore, it is crucial to conduct additional research aimed at discovering efficient mulching materials and preemergence herbicides for weed control during propagation, while preserving root initiation, plant development, and growth.

## Keywords

Herbicides, Mulch, Nursery Crops, Propagation, Weeds

## 1. Introduction

Weeds compete with crops for nutrients, light, and water and hence affect the growth and reduce the value of nursery crops [1]. Moreover, weeds can harbor different types of pests including insects and plant pathogens that can damage

crops [2] [3]. Some weeds also produce allelopathic chemicals which can suppress the growth of surrounding plants [4]. Weeds are the major problem in nursery crop production, but the problem is more intense in propagation due to the small container volume [1]. Competition for nutrients, light and water is more in smaller containers than in larger containers [5].

Due to weed infestations, nursery growers have been facing economic loss of about $7000 per acre [6]. Even a single weed in a nursery container can have a huge impact on the growth of the plant and can lower the market value of the product [7]. In ornamental plants, weed competition is more detrimental as their interference can lower its vigor, reduce leaf size, and fewer flowers [8]. Norcini and Stamps reported that due to weed competition from large crabgrass *(Digitaria sanguinalis*) there was 60% less growth of "Convexa" Japanese holly (*Ilex crenata*) grown in 3.7-liter containers [9]. The shoot weight of "Fashion" azalea (*Rhododendron*) was found to be reduced up to 78% by eclipta (*Eclipta alba*), depending on the size of the container and number of eclipta weeds per container [5]. Plants with reduced leaves and few flowers can result in decrease aesthetic value and hence lower prices. Some crops may require extra time to reach marketable size due to weed infestation [8]. Weed infested containers are less attractive to consumers which can lead to reduced sales and profits [10]. Additionally, propagated crops are more susceptible to weed competition as they do not have well developed root system. Although hand weeding is necessary for removing existing weeds, herbicides can be a cost-effective tool for weed control [11]. But no preemergence herbicides are labeled for use on unrooted cuttings [12] [13] [14]. Also, there is limited research on evaluating herbicidal safety and activity during propagation and root initiation [15]. Hence, the objective of this study is to review some of the current weed control practices along with most effective corroborated techniques in propagation highlighting the knowledge gap for further research. In this study, we review the weed control methods, challenges and effectiveness of herbicides and mulches in propagation. We structure the paper to cover method of propagation of woody ornamental crops in field beds and containers, challenges of weed control in propagation and different weed control techniques including herbicides, mulches, and cover crops.

## 2. Propagation of Woody Crops

Nursery crops include a variety of plant types including ornamental trees, shrubs, herbaceous perennials, and fruit and nut plants. Floriculture includes bedding/garden plants, cut cultivated greens, cut flowers, flowering potted plants, and foliage plants [16]. There is diversity in production practices for nursery crops and floriculture crops such as greenhouse production, container production and field production. Propagative material is produced commercially for the purpose of selling to nurseries/greenhouses for growing on to a finished product and includes seedlings, bulbs, divisions, unrooted cuttings, rooted cuttings, or plants in tissue culture. Some plant species are very difficult to propagate from

seed or may not produce viable seed, but they can be easily propagated asexually. An advantage of producing plants through asexual propagation is the higher cash value placed on clonally regenerated cultivars [17]. Also, plants produced from seed tend to have a relatively high amount of genetic variation, but asexually propagated plants assure preservation of the original genotype. Propagative materials are produced in an area of 24,192 acres with sales of $753 million annually in United States (U.S. Department of Agriculture, 2019).

Compared to all other methods of propagation, cuttings from stems, leaves, roots, or terminal buds are the most applied technique as it is simple and practical method of propagation [18]. For several plant species from herbaceous to woody plants, stem cutting is the most common method of vegetative propagation. Also, outdoor field nurseries are prepared, and seeds are sown for producing seedlings for conifers and deciduous plants for forestry, for ornamentals, fruit and nut trees and some vegetable transplants. Cultivars are budded or grafted to the seedling in place. This method is used to propagate shade trees and ornamental shrubs, either as seedlings or on rootstocks as budded selected cultivars. Most of the woody ornamentals, including some shade trees, are propagated by cuttings. Hardwood cuttings are most often used in propagation of deciduous woody plants. Also, some broad-leaved evergreens can be propagated using hardwood cuttings [17].

## 3. Methods of Propagation for Woody Ornamental Crops

### 3.1. Seedling Propagation in Field Beds

Seedling growth mainly depends on light, temperature, water, and nutrient availability [19]. Hence, the site for the seedling propagation should be fertile, well drained and weed free. Common seed bed size is 1.1 to 1.2 m (3.5 to 4 ft) wide, but the length varies according to the size of the operation. Seeds are either broadcast over the surface of the bed or drilled into closely spaced rows with seed planters. The optimum seed density depends on species and nursery objective. After care such as continuous supply of moisture, control of weeds, proper disease control helps in successful seedling growth. When they are in desirable size, seedlings are pulled, bundled, and used as bare-root transplants [17].

### 3.2. Seedling Propagation in Container

In this method seeds are pregerminated to a primary leaf stage and then the germinant is directly sown (transplanted) into containers [20]. Seeds are planted in fall, spring or summer depending upon the dormancy of seed, the management practices of nursery, and temperature requirement of seed for germination [17]. In some container nurseries, seeds are sown in special trays and placed in greenhouse. When young seedlings begin to germinate from the germination medium, they are carefully removed and transplanted into another container. The growing medium is firmed around the transplanted seedling for ensuring

good root contact, and then the seedlings are allowed to grow. This technique can be adopted in a condition when seeds require long or variable cold, moist stratification treatments, seeds with complex dormancy or if seeds are from large-seeded species [21].

### 3.3. Stem Cuttings in Field Bed

The success of stem cutting propagation depends upon various factors such as status of mother plant, type of culture media, rooting hormones, and environmental conditions such as light, temperature, air humidity and soil moisture during propagation [22]. The timing and type of cutting which are the key for the successful propagation highly dependent on the species. The growth timing of the plants is not constant every year as it is influenced by the environment, fertilization, and irrigation schedules. Thus, there should be flexibility while scheduling propagation by softwood or semi-hardwood cuttings, up to several weeks from year to year [23]. Cuttings can be treated with Auxin as it may hasten root initiation, increase root number and quality, and increase the percentage of cuttings that form roots [24] [25]. Propagation beds should have proper drainage systems to drain extra water. Field propagated hardwood cuttings are dug after a growing season as rooted liners using an apparatus such as U blade attached to a tractor.

### 3.4. Stem Cuttings in Container

Growers propagate by sticking cuttings in small containers (rose pots) and then place them under mist in greenhouses or outdoor ground beds [15]. Cuttings can also be rooted in special trays and then transplanted into growth containers or stuck directly into the containers [21]. In commercial production many growers stick cuttings directly into individual pots. Firstly, pots are filled with media, placed in flats, and then the flats are moved to the propagation house 1 - 2 days prior to sticking the cuttings. During this period, the pots are watered thoroughly to wet the medium [15].

## 4. Challenges of Weed Control in Propagation

Once weeds become established during propagation, very few weed control options are available to growers. Hand weeding is the most common method of weed control during propagation, but it is time consuming and labor intensive. Depending on nursery size, annual hand weeding costs range from $608 to $1401 per hectare ($246 to $567 per acre) based on hourly wages from $3.53 to $3.97 [13] [26]. Also, recently there has been a decrease in availability of agricultural labor supply [27]. Although propagative material requires less space compared to finished crops, the high-density plantings intensify the effects of weeds and make hand weeding difficult. It is evident that hand cultivation of 12-week-old hardwood seedlings has caused an 8% mortality [28]. Hand weeding in propagation can suppress growth of cuttings through mechanical disrup-

tion [15].

Soil fumigants are often used for nursery seedlings and propagation beds as an effective method of weed control. Seed beds are fumigated by soil sterilant such as methyl bromide/chloropicrin or methyl isothiocyanate. Fumigation is expensive, but eliminates all common nursery pests; pathogenic fungi, insects, nematodes, and weed seeds [21]. Among the different categories of fumigants, methyl bromide, dazomet (Basamid) and metham-Sodium (Vapam) are mostly used in propagation greenhouse and field seedbeds [29] [30]. Likewise, for pest management, dozomet (Basamid) and metham-sodium (Vapam) are the widely used chemicals [31]. Since Vapam is a liquid, it may be easiest to use on small areas as a liquid drench and as dazomet (Basamid) is a granular material, it is easy to apply with a spreader. In some situations, injury to adjacent crops has occurred when dazomet or metham-sodium was applied without a tarp [32] [33]. Also, these chemicals are very toxic and can kill both wanted and unwanted organisms [34]. With fumigation, the primary means of weed control, costing over $24,711/ha ($1000/A) and the problems with reducing endomycorrhizal fungi [35]. As methyl bromide is responsible for depleting the ozone layer so many countries including the United States has phased out production and consumption of methyl bromide with important exceptions for critical uses as well as quarantine and pre-shipment. In this case, possible alternatives include chloropicrin and dazomet. Although both can control certain soil-borne pests, neither is as effective in controlling nutsedge as methyl bromide [36] [37].

At the present time, herbicides are the most widely used and effective tools for weed management in the commercial landscape and nursery industry. Herbicides are currently used on 90% of all U.S. cropping acreage [38] [39]. The use of herbicides in container-grown nursery production became standard practice in the 1970s. However, there are a limited number of herbicides available for use in the ornamental plant industry [7] [39]. The use of herbicides in container-grown ornamentals is limited due to the lack of registered herbicides for greenhouses and it is very difficult to assure crop safety on the wide range of crops grown in ornamental nurseries [40]. Moreover, there are further few herbicides labeled for the use in propagation. Currently, no herbicides are labeled for use on crops growing in an enclosed structure such as a greenhouse. Additionally, since propagation is mostly done inside closed structures, use of preemergence herbicides is not a wise option [41]. However, in the Southern United States, growers propagate many evergreens nursery crops in shaded outside beds during the summer, which reduces the risk of herbicide use in enclosed areas [14]. These herbicides are restricted to being used inside enclosed structures due to fear of volatilization and co-distillation of the herbicide and subsequent plant injury. Some preemergence herbicides can cause damage to crop by leaching into the root zone. Leaching is mainly due to the porosity of the container substrate and the quantity of the water applied to the container [42]. Horowitz and Elmore conducted a leaching experiment in columns of soilless substrate potting media

and field soils where oxyfluorfen was incorporated into the upper 2 to 4 cm of each material [42]. They noted that, there was less leaching in substrate containing peatmoss than bark. In soilless substrates, herbicide leaching may be due to the large macropores present in pine bark-based substrates allowing herbicide to leach into the root zone [1]. In addition, stunted root and shoot growth was observed with the application of oryzalin in abelia (*Abelia* × *grandiflora*) when applied to a bark substrate and concluded because of leaching to the root growth zone [43].

Furthermore, most of the preemergence herbicides that are used in nurseries contain dinitroanilines (DNAs) which inhibit root growth. In propagation environment, irrigation is used frequently due to which irrigation water moves the herbicide near to the root system and hence will inhibit the root development [15] [41] [44]. Dinitroaniline-containing herbicides are more injurious as compared to herbicides which do not contain DNA. Therefore, non-DNA preemergence herbicides have potential and should be considered for use in propagation.

Much of the previous work has shown that preemergence herbicides can be used in propagation beds but they have also shown injury to the crops. In several studies, surflan (Oryzalin) has shown reduction in the rooting percentage, the number of roots per cutting, and the rooting quality [15] [45]. The mode of action of oryzalin is root growth inhibition and the result is valid [46]. In another study, Barricade (prodiamine) which is also a root-inhibiting herbicide has reduced the rooting of azalea (*Rhododendron obtusum*) cuttings [12]. Detrimental effects of preemergence herbicide were revealed by the study of Thetford and Gilliam where they observed oryzalin caused a reduction in rooting percentage, primary root numbers, and root ratings of Foster's holly (*Ilex* × *attenuata Ashe* "Fosteri") [17]. In a separate experiment, they reported after 13 months of growth, oryzalin suppressed root and shoot growth of "koreana Nakai" Korean boxwood (*Buxus microphylla* var. "koreana Nakai") and suppressed root growth of "Compacta" Japanese holly (*Flex crenata Thunb* var. "Compacta"). A study reported that the rooting percentage of "Hino Crimson" azalea (*Rhododendron obtusum* var. "Hino Crimson") was suppressed with oxyfluorfen + oryzalin. Root quality ratings and root lengths of "Trouper" azalea (*Rhododendron* var. "Trouper") and "August Beauty" gardenia (*Gardenia jasminoides* var. "August Beauty") were generally lower with oxyfluorfen + oryzalin, oxyfluorfen + pendimethlin, trifluralin + isoxaben, and pendimethlin when compared to the non-treated control [11]. In one of the recent studies, Broadstar (flumioxazin) was found to damage nonrooted cuttings of several nursery crop species. Because of the risk of crop injury and safety issues on rooting the use of residual herbicides is generally not recommended in propagation [46].

## 5. Importance of Sanitation Practices for Weed Control in Propagation

Proper sanitation practices are used to minimize introduction of weeds to crops

and sanitation is a critical component of a weed management program for propagation. The sources of weed seed include container substrates, weeds growing in or near the propagation area, and from containers being re-used from previous crops [46]. Substrate can be infested with weed seeds from the weeds present near to production beds or substrate piles. To prevent the introduction of weed seeds in the mixed piles, they can be covered to limit the exposure to wind-blown weed seeds [7]. Weeds can be introduced from the surrounding areas by wind, physical dispersal, and encroachment by rhizomatous and stoloniferous weeds. Therefore, weeds present around potting areas, substrate storage areas, container beds, and propagation areas must be removed early before they flower and produce seeds [46]. Also, weeds grown in non-crop areas such as roadways, drainage ditches etc., must be removed. This can be done by regular mowing, mechanical removal such as hoeing or plowing or by using postemergence or preemergence herbicides [1]. Irrigation water can also be one of the sources for the introduction of weeds if the water is from a lake, pond, or river. To avoid this contamination of irrigation water, screens can be used at the intake pipe which can help to filter out large-seeded weeds. Mulching materials can also be a major source of weed hence, selection of the mulching material should be done wisely. New bark or sawdust mulches can be used as they are found to be relatively free from the weed [47]. When re-using containers, efforts must be made to properly clean the pots. It is important to wash the pots both inside and out to ensure that all remaining soil or potting substrates are removed.

## 6. Herbicide Use in Propagation

### 6.1. In Container

It is reported that some of the non-root-inhibiting herbicides such as Ronstar (oxadiazon) and oxyfluorfen (several granular formulations containing oxyfluorfen) did not reduce rooting percentages of a wide variety of woody nursery crops [15] [45] [48]. Root-inhibiting herbicides with lower water solubility than oryzalin, including pendimethalin and prodiamine, did not inhibit rooting of azalea (*Rhododendron × obtusum*) cuttings [45].

Studies were conducted to evaluate the effect of herbicides [Gallery (Isoxaben), Ronstar, and Regal O-O (Oxyfluorfen and oxadiazon)] during propagation of Ruby (*Loropetalum chinense*) on rooting and subsequent plant growth. Herbicides were applied in single applications at three different timings: before sticking, lightly rooted cuttings, or fully rooted cuttings. Growth indices of Ruby were similar regardless of herbicide treatment one year after sticking. Ronstar applied before sticking and at lightly rooted stage suppressed root growth, while Regal O-O suppressed root coverage on all three timings of application [49]. The experiment by cook and Neal suggested that there is a potential for non-root-inhibiting herbicides to be used in propagation [12]. From their experiment they concluded that Ronstar, Regal O-O, and Broadstar (flumioxazin) can be

used for the preemergence control of weeds at the time of sticking during propagation of woody liners, but further research is needed. The root inhibitors, such as Regalkade G (prodiamine), should not be used until cuttings are fully rooted. When Gallery was applied to lightly and fully rooted cuttings of "Ruby" loropetalum there was not any negative impact on shoot or root growth. This glaring evidence suggests that Gallery could safely be used in "Ruby" loropetalum propagation after the rooting process has begun, which is about the time when bittercress starts to become a problem in recently stuck cuttings [14].

It is also evident that, when rout 3G (oxyfluorfen + oryzalin) and Snapshot 2.5TG (Isoxaben + Trifluralin) were applied just prior to sticking of the cuttings of "August Beauty" gardenia at the depth of 2.5 cm (1.0 inch) into the soilless rooting medium improved root development compared to 1.3 cm (0.5 inch) [11]. Non-root inhibiting herbicides such as Ronstar (oxadiazon) and several other granular formulations containing oxyfluorfen were tested. These herbicides did not reduce rooting percentages of a wide variety of woody nursery crops [12] [15] [45] [48]. PRE herbicides pendimethalin, dithiopyr, and prodiamine provided effective weed control in several herbaceous perennial species with little or no plant injury [50].

### 6.2. In Field Beds

Glyphosate and Paraquat-RoundupTM or Gramoxone is applied as a preemergence herbicide to seedlings in all seedbeds. Also, Simazine-Princep Caliber 90 is applied both as a pre- and postemergence herbicide to seedlings with residual activity on many grass and broadleaf weeds. Prodiamine-Endurance or Barricade, Oxyfluorfen-GoalTM, Fluazifop butyl-Fusilade is applied as a post-emergence herbicide in seedling beds [51]. Goal2E (oxyfluorfen) is the only preemergence herbicide labeled for use in seedbeds. Envoy and Vantage may be applied directly over the top of conifer seedlings; however, it is advisable to avoid applications when very young. Ronstar (oxadiazon) may be used for preemergent control of annual grasses and some broadleaf weeds. In an experiment done in tree seedling beds, the herbicides Isoxaben and Napropamide were very effective in controlling weeds [52]. However, their effectiveness in controlling grass weeds was poor.

In a study, preemergence herbicides were applied in seedling of *Acer rubrum*, *Quercus phellos*, and *Ulmus pumila*, *Siberian elm* which were about 2 - 3 tall with at least four sets of true leaves and red maple and willow oak were on a two-year production cycle. At 30 DAT factor, Gallery, Princep and Surflan stunted the seeding. But at 90 DAT, all seedlings were uniform in plant growth with no discernible differences in size. In the same study, the two-year-old red maple and willow oak seedlings were treated with the same herbicides (Factor, Gallery, Princep and Surflan, Rout) and rates. There were no discernible differences among the treatments at 15, 30, 60 and 90 DAT [53]. In addition, applications of napropamide + pendimethalin appeared to be safe on seedlings of hazel

(*Corylus avellana* L.), beech (*Fagus sylvatica* L.) and ash (*Fraxinus excelsior* L.). Also, the mixture of pendimethalin + napropamide was tolerated by sycamore (*Acer pseudoplatanus* L.) and hawthorn (*Crataegus monogyna* Jacq.). Whereas applications of napropamide alone were moderately tolerated by hornbeam (*Carpinus betulus* L.) and dogwood (*Cornus sanguinea* L.) [54].

## 7. Alternative Weed Control Methods

### 7.1. Mulches

Mulches can be one of the important alternatives for controlling weeds in containers. For container-grown crops, mulches are applied to the substrate surface to create a physical barrier which will inhibit weed seed germination and suppresses weed growth [55]. Loose-fill mulches include bark from various tree species including pine, eastern red cedar and douglas fir (*Pseudotsuga menziesii*) [56]. Also, many loose-fill mulches are agricultural by-products that are available locally and are relatively inexpensive [57]. Waste products such as newspapers can also be excellent material which can be used as mulch [58]. Newspaper pellets at 5 cm (2.0 inch) depth-controlled spurge in the landscape for at least 60 days [59]. However, wastepaper has been shown to reduce available nitrogen when applied to container surface as mulch [60].

Pine bark mini nuggets can also be an option for the non-chemical control of the weeds. Properties such Low fertility, large particle size and hydrophobic properties of pine bark nuggets create a not conducive environment for weed growth [61]. Shredded pine bark mulch has provided good weed control in the landscape and is generally accepted by consumers [56]. Rice hulls are used as a component in greenhouse and nursery substrates. They can also be used as container mulch. One manufacturer (Riceland Foods) recommends a rice hull mulch depth of 3.8 to 5.0 cm for effective weed control in container crops [62]. Rice hull mulch at a depth of 2.5 cm provides excellent control of flexuous bittercress (*Cardamine flexuosa*) and liverwort (*Marchantia polymorpha* L.) when seeds are disseminated onto the mulch surface [63]. Likewise, parboiled rice hulls have been shown to provide effective weed control when applied 1.25 to 2.5 cm deep over the container substrate surface. Establishment of both weeds decreased with increasing mulch depth. The hydrophobic nature of rice hulls Lack of water is discussed as the primary mechanism of weed control above the mulch layer [62].

Mustard seed meal when applied to surface of the container substrate, reduced weed counts of annual bluegrass (*Poa annua* L.) by up to 98%, common chickweed by up to 74%, creeping wood-sorrel by 90%, and provided up to 97% control of liverwort (*Marchantia polymorpha* L.) [40]. In another study, when applied to the surface of container-grown ornamentals, dried distiller grains with solubles, a byproduct of ethanol production, provided 40% to 57% reduction in weed control of annual bluegrass and 33% to 58% reduction in common chickweed and did not reduce the growth of *Coreopsis auriculata* "Nana", *Rosa hybr-*

*id* "Red Sunblaze", or *Phlox paniculata* "Franz Schubert" [64]. Also, wood pellets were safe and effective on reducing weed populations in nursery containers. In the long run pellets start to break down upon the application of water to form the saw dust barrier that completely covers the soil surface [65].

With the limitations in the weed control methods in propagation, mulches such as rice hulls, paper pellets, pine bark nuggets and other loose mulches can be used for controlling weeds in propagation. Some mulches such as disk barriers are not practicable in small containers. Propagation is mostly done in small containers, so mulching materials having less volume will be applicable. Also mulches to be used in propagation should not contain any chemical compounds affecting the rooting. But there is very few research on the use of mulches in propagation. Based on the reports with mulches used in container and on limited reports with the use of mulches in propagation, there is a need for further investigation on efficacy of mulches in propagation.

### 7.2. Living Mulches/Cover Crops for Field Beds

Living mulches or cover crops are used as a seasonal ground cover that suppresses weeds without competing with crops [57]. There are tremendous benefits of using living mulch in horticulture crops which includes reduced weed competition, soil stabilization, decreased fertilizer and pesticide needs, and increased soil moisture retention [66] [67] [68]. Also, Cover crops can prevent the development of weed population, control the soil disease, soil enrichment through nitrogen fixation in soil, improve soil structure, preventing absorption of nitrogen, increase soil organic matter and reduce leaching [69]. Living mulches are being used by many field nurseries crops grower with great success for weed suppression [70] and can be adapted to container production [71]. Residues of the cover crops on the soil can alter the seed germination environment (changes in light availability, soil temperatures, and soil moistures) in the soil.

The "living mulch" protected the fall-sown seedbeds from injury by wind, rain, and frost. In Georgia and Tennessee nursery growers sow wheat (*Triticum aestivum* L.), rye, or oats (*Avena sativa* L.) on prepared beds before fall sowing acorns (*Quercus* sp.) [72]. The living mulch is then sprayed with an herbicide in February before emergence of oak seedlings which have several advantages, including a retardation of weed growth [37]. In an experiment red clover and ladino clover were used as a living mulch and they showed acceptable result for suppressing weed population when use with the hardwood and pine seedlings, respectively [73].

## 8. Conclusion

Weeds are a major problem in the cutting propagation environment, competing for resources and reducing crop growth and quality. There are very limited options for controlling weeds in propagation which make weed control challenging. Hand weeding is the most common method for controlling weeds in nur-

sery crop propagation, but it is time-consuming and costly due to high labor cost. Other methods such as sanitation and soil fumigation (field beds) are adopted for preventing the weed in propagation. Preemergence herbicides may effectively control weeds in propagation environment, but no preemergence herbicides are labeled for use in propagation and nursery growers remain reluctant to use these products due to the safety issue on rooting. Mulches are widely used for controlling weeds in production with high success, but they are not widely evaluated in propagation environment. Combination of herbicides and hand weeding can also give acceptable level of weed control and crop safety. Although numerous studies have been reported on the effects of preemergence herbicide and mulches during crop production, few studies have evaluated these products for cutting propagation. Although some preemergence herbicides can be injurious to sensitive crops and may hinder root development, certain products may be safe to use during propagation. Mulches can also provide effective weed control during crop production, but mulch type and depth may affect rooting of cuttings and weed control efficacy. Identifying effective weed control strategies for propagation will ultimately lead to greater crop quality and reduce the overall costs for growers. Hence, further research is important to find effective mulches and preemergence herbicides for controlling weeds in propagation without effecting the root initiation and plant development and growth.

## Author's Contribution

All authors contributed equally.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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