

REVIEW ARTICLE

# A Review of Root Pruning to Regulate Citrus Growth

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## Abstract

Root is the important plant organ hiding below the soil that serves as plant supporting structure, water and nutrient supplier and assimilates storage. Root growth occurs in turn with shoot part, forming repeated cyclic pattern because of the photosynthate competition. Root growth regulation is one of the promising practices to boost the yield of fruit tree, especially citrus that is economically important and highly demanded fruit. Root pruning varied based on the scale of intensity and plant growth stage, including air root pruning, knife root pruning and modern pruning using root pruner machine mounted to a tractor. Root pruning to induce the growth of more fibrous root system and to correct root deformation at seedling stage have potentials to improve post-transplant growth. Besides, it has a potential to replace the use of chemical plant growth regulator for a more environmentally friendly practice. The pruning of root impeded the canopy growth, altered the plant water status leading to flower promotion. In addition, it is also a promising practice to overcome the alternate bearing on fruit tree, including citrus, through the suppressing of excessive growth and restricting the high fruit load during the 'on year' and allowing a better carbohydrate storage for the improvement of yield during the 'off year'.

Keywords: alternate bearing, fibrous root, flowering, root pruner, root deformation

## Introduction

Root is one of the plant organs commonly found below the soil with the positive geotropism growth direction to approach the water or nutrient source (Tjitrosoepomo, 2009). In general, there are two types of plant root systems, taproot and fibrous root. The taproot root system is characterized by the presence

of the big and thick main root, with minimal branching, while the fibrous root system is dominated by fibrous root with the absence of main root (Harris and Harris, 2006). Taproot system is generally found in dicots, while monocots exhibit fibrous root system (Mulyani, 2006).

Unlike the stem, the roots of plants are not segmented, not hooped and also not attached by the foliage. In contrast to the leaves that are usually green, the roots are more often found in white or yellow color. Compared to the above ground canopy parts such as stems or leaves, roots get less attention because their existence is underground. Roots have an important role in supporting the growth of plants, such as providing support to stems and shoots above the ground, supporting water and nutrients absorption, and serving as nutrient storage in some species (Tjitrosoepomo, 2009).

Attention to plant rooting system is important to have a good plant growth and development. A good proportion of the root to shoot system in plants is important; a better proportion of root to shoot can be achieved through root pruning. Pruning is an attempt to rejuvenate and maintain tree sizes including canopies and roots to be ideal for optimum production (Widodo, 1995; Marini, 2014). Pruning of plant root is actually an old manipulation technique applied to arboriculture, including landscape and forest tree nurseries (Gilman, 1992), however, the effects have not been clearly reported on fruit, including Citrus.

Citrus is one of the economically important fruits in the world (FAO, 2015) and is one out of three strategically horticultural commodities in Indonesia (Dirjenhort, 2016). It is top second favorite fruit after banana, with the rate of consumption about 2.71 kg/capita/year on 2014 (Susenas, 2014). Improvement of social welfare on urban area lead to the rise of fruit consumption, especially citrus (Darmawan et al., 2014). However, the Indonesian citrus production has declined by 1.5%

during the past few years (BPS, 2015), leading to the rise of importing rate from overseas by more than 80% (Pusdatin, 2015). To meet the demand for citrus fruits the domestic citrus production could be rapidly increased through growth regulation practices. Plant growth can be manipulated by various practices, both on canopy and root. Most of studies revealed the success of manipulation on canopy to gain desirable effect, such as bending, defoliation, strangulation, girdling, ringing and canopy pruning (Poerwanto and Susila, 2014; Budiarto, 2018). However, the growth regulation practice on root, like root pruning, is less often studied, indicated by the limited number of reports available. Therefore, this article aimed to review the potentials of root pruning to regulate the plant growth and development, especially in citrus.

### Citrus Root Growth Pattern

Citrus is classified as dicots plant with its tap root system, indicated by the presence of dominant main root and the rest are fine roots. In average, the root of Citrus can last up for 16 to 348 days, depend upon the genotypes and growing medium (Eissenstat and Yanai, 1997). Bevington and Castle (1985) reported that lemon citrus has the capability to maintain the fine roots over 100 days. The growth of citrus root is highly influenced by the temperature and water content of soil surrounding the root zone. In the case of Citrus, soil temperature above 27°C supported rapid root growth, while soil temperature below 22°C could slow down the root growth. The elevation of soil temperature decline soil water content and limit the nutrient uptake, enhance root respiration that wasted a lot of energy and eventually impeded the root growth (Bryla et al., 1997). The root growth still can be reversible after re-watering, although it needs to have a lag period for two days (Bevington and Castle, 1985). When soil temperatures were elevated from 25 to 35 °C root soil respiration rate suddenly increased, whereas a reduction of temperature from 35 to 25 °C immediately decreased respiration (Bryla et al., 1997). It is likely that soil temperature is an important factor controlling daily fluctuations in respiration. Although the temperature and water content in soil stand in normal condition, the root growth could delay due to the dominant shoot growth in form of flushing. Shoot and root grow alternately, forming a cyclic pattern (Bevington and Castle, 1985; Septirosya, 2016; Budiarto, 2018). Annually, two to three cycles can occur in citrus trees grown under subtropical area. In the tropics, including in Indonesia, the flushing cycle of mandarin citrus trees is consistently occurred in every two months, composed of a month of shoot elongation period and another month of shoot dormancy period (Budiarto, 2018) that might be used for root growth. The alternate shoot-root growth

pattern also displayed in young mandarin citrus grown in root box (Septirosya, 2016).

The alternate pattern of citrus root growth indicated the presence of assimilates competition between the shoots and the roots (Figure 1). During the flushing period, the shoots are stronger sink than the roots. A rapid number of proliferated shoot need a high support of assimilates and supply a high auxin to the lower plant part, leading to the decline in root growth. Following the cessation of flush elongation, the auxin supply in root is decreases, allowing the root to speed up its growth (Bevington and Castle, 1985).

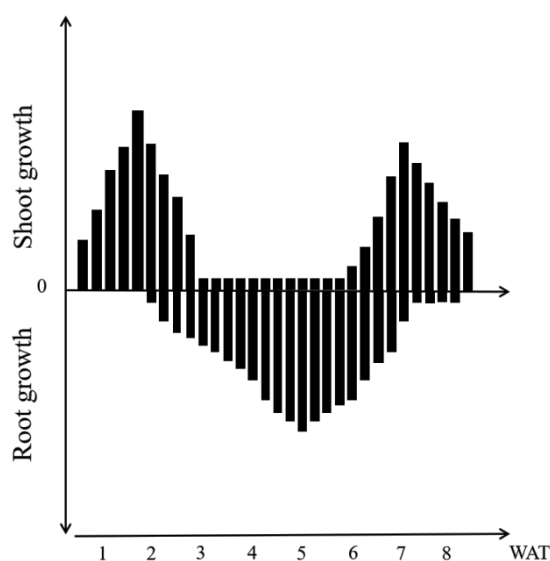


Figure 1. Alternate pattern of shoot-root growth in mandarin citrus (*Citrus reticulata* Blanco) during nine weeks after treatments (WAT) (Redrawn from Septirosya, 2016).

### Root Pruning Techniques

The various techniques have been applied to prune the plant roots. Most of the techniques were applied directly in field at an orchard scale, although some techniques were developed for potted plants or seedlings. In the case of potted trees Ouma (2008) trimmed the root by inserting a shovel in growing medium at about 5 cm around the stem. In the case of seedlings, there are two methods reported, i.e. air pruning and knife pruning. Air pruning can be used to boost the growth of citrus seedling. The basic concept of air pruning is allowing the dry air to contact with the root tips so the root stop to elongate and produce the root branch so that is high fibrous root formed. This practice has been used in the nursery by using a modified pot for air pruning (Hydrocentre, 2014) or even placing the common tray on the bench to allow the air circulation below the tray (Widodo, 1995). Knife pruning has been used by traditional citrus

growers in Garut, West Java, Indonesia to accelerate the flowering. The practice requires a sharp and sterilized knife to cut the taproot of seedling about 5 cm below the base of the stem prior to transplanting. Following root pruning, the mandarin citrus will flower at 22 months after planting (MAP), or it was a year earlier than the normal ones, i.e. 36 MAP (Abdussalam, 2014). These results were supported by previous studies that root pruning at seedling stage could increase the transplant survival and also post-transplant growth (Grim, 1956; Mullin, 1966).

In a large scale plantation root pruner is used. Root pruner is commercial machine to trim the plant root that consisted of sharpened subsoilers mounted to the tractor (Schupp and Ferree, 1987; McArtney and Belton, 1992). Root pruners can be run in inter-row sides or even surrounding the tree trunk. The tractor generally runs at very low speed of around 5 km per hour. However, the detail of operational of root pruner may differ from one orchard to another according to the growers practical experiences (Gilman, 1992). Previous studies frequently reported the application of root pruning in the apple orchard. Schupp and Ferree (1989) pruned apple tree roots annually at full bloom stages to a soil depth of 25-50 cm, at 60-80 cm from the trunk, on two opposite sides of the apple tree. McArtney and Belton (1992) used to prune their eight-year-old apple tree to a soil depth of 30 cm, at 60 cm from the trunk. Ferree (1992) pruned the apple root to soil depth of 40 cm and at 60 cm from the trunk. Later on Ferree (1994) adjusted the root pruning of the apple root to soil depth of 25 cm and at 80 cm from the trunk, because the roots were highly concentrated to soil depth of 30 cm. Root pruning should be applied at the best time to achieve not only optimum desirable reductions in form of plant growth and pre-harvest drop, but also minimum undesirable reductions in fruit quality and quantity. After a series of experiment, the best time of root pruning in apple was decided to be once a year, at full bloom stages and repeated for six to nine years (Ferree, 1992; Ferree, 1994).

Other recommendations were developed for southern magnolia, winter jujube and pear trees. Gillman (1992) applied root pruning on southern magnolia to a soil depth of 30 cm, at 38 cm from the trunk by going around the trunk. Yang et al. (2010) classified the level of root pruning on 6<sup>th</sup> years winter jujube based on the distance of the blade entry point. The blade entry point for severe, moderate and light pruning were 3, 5 and 7 times of the diameter of the trunk, respectively. The blade trimmed the soil containing plant root to a depth of 20 cm. Wang et al. (2014) applied root pruning on 11<sup>th</sup>-12<sup>th</sup> pear orchard by using root pruners mounted to a tractor and trim

the roots to a depth of 30 cm and at 40 cm from the main trunk on both sides of pear tree.

#### Root Pruning for Correcting Root Deformation

Root deformation is an abnormality of root morphology such as kinked root, matted root, and twisted root (Arnold and Young, 1991), as shown in Figure 2. Root deformation is frequently found in plant that is growth under limited root volume, such pot, polybag or other container. Containerized plant concept is highly used in horticultural practice especially during the production of plant seedling. This technique is practical, space-saving, easy to transport and allows to delay planting date (Poerwanto and Susila, 2014). The disadvantage of this technique is that it caused root deformation leading to the reduction of vigor and mechanical stability of the seedling (Nussbaum, 1969; Preisig et al., 1979; Nichols and Aim, 1983).

Correcting root deformation at transplanting season could improve transplant survival and subsequently boasting post-transplant growth (Mullin, 1966). The correction could be reached through root pruning technique (Harris, 1983; Widodo, 1995). Root pruning have been applied by mandarin citrus farmers in Indonesia during the transplanting period for preparing better growth in the subsequent year (Widodo, 1995; Abdussalam, 2014). It should be done carefully because trimming roots too much caused the physiological stress to the plant, lead to the growth inhibition (Poerwanto and Susila, 2014). Arnold and Young (1991) reported that the few adverse effects caused by root pruning was found in plant with small amount of removed root, i.e. 19-27% of whole plant biomass in fresh weight basis.

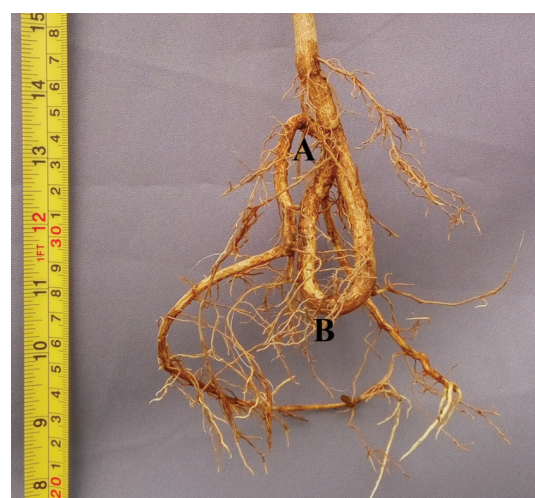


Figure 2. Root deformation in mandarin citrus (*Citrus reticulata* Blanco cv Borneo Prima) seedling, indicated by (A) kinked root and (B) twisted root

### *Root Pruning to Induce Fibrous Root Formation*

Unlike the monocots with its natural fibrous root system, citrus or other dicots have taproot system with the less root branching. More fibrous roots on dicots would be an advantage to enhance the absorption of water and mineral from the top soil, the more the fertile part of the soil. Root pruning is potential to be applied to gain more fibrous root on dicots, like Citrus. Root pruning in the nursery can stimulate the seedling to produce more compact, dense, and fibrous root (Watson and Sydnor, 1987; Arnold and Young, 1990; Raharjo et al., 2017; Louk and Raharjo, 2017) that is associated with better post-transplant performance.

The response of plants to root pruning varies depending on plant species and environmental conditions. In case of Citrus, following 50% root pruning, the sugars were immediately transferred to root part to ensure sufficient nutrient stock for the new root growth. At the same time of new roots grow and the shoot growth is ceased to limit the nutrient competition of shoot and root (Syvertsen and Hanlon, 2008). Most of the new roots formed were tiny and branched, forming more dense and fibrous roots. New roots usually initiated at least 10 cm below the pruning point (Gilman, 1992). Following pruning, the roots will be highly concentrated in the top soil layer (Wang et al., 2014), especially the upper 10 cm of top soil (Koukoura and Menke, 1994). This root growth continued until the newly formed roots were similar to the amount of roots previously removed, or at least to restore the pre-pruning shoot and root ratio (Gilman, 1992).

### *Root Pruning to Promote Flowering*

Root pruning is traditionally used by mandarin citrus farmers in Garut, West Java, Indonesia to promote earlier flowering from 36 months after pruning (MAPr) to 22 MAPr (Abdussalam, 2014). Promoted flowering could occur because of the acceleration of vegetative growth of the seedling due the correction of root deformation, and production of more fibrous roots, as described previously.

In other cases, especially in fully developed trees, root pruning can retard the top growth and subsequently accelerate flowering (Mullin, 1966; Gilman, 1990; Gilman, 1992). This desirable effect of root pruning has potentials to replace the application of commercial chemical retardant (Wang et al., 2014) including cyclocel, diaminozide, morphactin and paclobutrazol (Lizawati, 2008). The improvement of flowering response as root pruning effect on mature tree has been reported in apple (Khan et al., 1998), mango (Ali et al., 2014) and peach (Tsukahara et al.,

2009). The flowering may be caused by the stress as a result of root pruning, especially at moderate level of pruning (25-50%). Stressed trees showed the decline in leaf water potential and leaf stomatal conductance (Ali et al., 2014). This physiological response is similar to drought stress that could induce flowering of mandarin citrus grown in the tropics (Srivastava et al., 2000; Poerwanto and Susila, 2014)

### *Root Pruning to Overcome Alternate Bearing*

Alternate bearing is a unique phenomenon indicated by repeated cycles of high and low yield period that frequently occurs in some species of fruit tree. The high yield period is known as 'on year', while the low one called as 'off year'. During the 'on year', the carbohydrate status (starch concentration) of the plant (leaves, bark and root) was depleted due to excessive support to the large sink in form of high fruit yield. In other hand, during the 'off year', the carbohydrate status increased and eventually higher than 'on year' to support the maximum yield on the following year (Goldschmidt and Golomb, 1982). This alternative pattern results in unstable production and price gaps that are less profitable for growers (Poerwanto and Susila, 2014). Some fruit growers overcome the problem using chemical agents to retard the excessive growth and slightly reduce the yield during 'on year', with the hope that there will be an improvement in yield during 'off year', so it can minimize the yield and price gap between 'on and off year'. Unfortunately, chemical agent is no longer used due to the environmental issues. One of promising technology to replace the commercial retardant was root pruning.

Root pruning has been reported to overcome the alternate bearing problem on citrus (Eissenstat and Duncan, 1992), apple (Schupp and Ferree, 1990), mango (Ali et al., 2014) and pear (Wang et al., 2014). The higher fruit loading during the 'on year' is caused by the excessive growth at that period. This practice can suppress the excessive growth during the "on year" (Gilman, 1990; Ferree, 1992) that is indicated by the low shoot number (Wang et al., 2014) and the reduction of shoot grow rate due to lowered net photosynthesis, transpiration, stomatal conductance and water potential (Geisler and Ferree, 1984). Additionally, the water and nutrient uptake capacity of trees is restricted under root pruning due to the damage occurred on root system (Vercammen et al., 2005). Under this situation, there is a limited supply of carbohydrate to support heavy fruit loads (McArney and Belton, 1992). It was likely that the desirable growth suppression is highly related to the alteration of plant water status as affected by root pruning (Schupp and Ferree, 1990). To secure a stable fruit

production, especially during the “off year”, there is a need of supplemental irrigation combined with root pruning treatment (Wang et al., 2014).

## Conclusion

The growth of citrus roots usually alternate with the shoots, forming a cyclic pattern due to assimilates competition. Both stimulation and inhibition of the plant growth could occur as a response to root pruning. The practice of root pruning vary based on the application scale and plant stage of growth; three methods of root pruning has been reported, air root pruning, knife root pruning, and pruning using root pruner machine mounted to a tractor. Root pruning has been reported to promote to the growth of more fibrous root system and can correct root deformation at seedling stage, leading to the improvement of post-transplant performances. Root pruning could potentially replace the application of chemical plant growth regulator which could results in an impeded the canopy growth, altered the plant water status leading to flower induction. In addition, it also promising practice to overcome the alternate bearing on citrus trees through suppressing excessive growth, restricting the high fruit load during the ‘on year’, and allowing a better carbohydrate storage for the yield improvement during the ‘off year’.

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