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Growth characteristics and dry matter partitioning in sweet cherry rootstocks

(Ciri-ciri pertumbuhan dan pembahagian bahan kering pokok penanti ceri manis)

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Key words: growth characteristics, dry matter partitioning, rootstock, vigour, growth regulators, sweet cherry

Abstrak

Percubaan rumah kaca telah dijalankan terhadap klon pokok penanti ceri manis di dalam bekas dan kebuk kabus. Kesan penggunaan perencat pengangkutan auksin, asid 2,3,5-triiodobenzoik (TIBA) dan scopoletin, yang merupakan sejenis perencat enzim asid indola-3-asetik oksidase, pada pertumbuhan dan pembahagian bahan kering bagi kedua-dua pokok penanti yang dicantum dengan sion 'Bing' dan kawalan dikaji. Kajian di dalam bekas menunjukkan nisbah akar:pucuk dan panjang ruas Mazzard (*Prunus avium* L.), Giessen (Gi) 148/1 (*Prunus cerasus* x *Prunus canescens*) dan Gi 148/8 (*Prunus cerasus* x *Prunus canescens*) bagi pokok penanti adalah berkadaran dengan kesuburan. Penggunaan scopoletin pada kadar 100 ppm mengurangkan panjang ruas, tetapi menambahkan lilitan batang pada semua pokok penanti. TIBA dengan kadar 100 μM tidak menunjukkan apa-apa kesan ketara terhadap penambahan saiz lilitan batang atau panjang ruas. Kesan ketara (p <0.05) pada pokok penanti diperhatikan terhadap pembahagian berat kering untuk daun, pucuk baru dan tua, serta akar baru dan tua. Pokok penanti Mazzard dan Gi 148/1 yang subur mempunyai lebih pembahagian bahan kering terhadap akar dan pucuk yang tua, tetapi kurang terhadap daun atau pucuk baru dibandingkan dengan pokok penanti Gi 148/8 yang kerdil. TIBA dan scopoletin tidak menunjukkan kesan yang ketara terhadap pembahagian bahan kering bagi bahagian tumbuhan yang berlainan. Keseluruhan pembahagian berat kering untuk daun, kayu dan akar bagi ketiga-tiga pokok penanti adalah masing-masing antara 15–22%, 44–48% dan 30–40%.

Bagi percubaan kebuk kabus, kedua-dua rawatan pokok penanti dan perencat tidak menunjukkan sebarang kesan ketara terhadap nisbah akar:pucuk, panjang ruas atau pertambahan lilitan batang bagi pokok penanti Gi 148/1 dan Gi 148/8. Tiada sebarang kesan ketara pada pokok penanti bagi pembahagian bahan kering di dalam percubaan kebuk kabus. Rawatan scopoletin dan TIBA tidak menunjukkan kesan yang ketara terhadap pembahagian bahan kering.

Abstract

Greenhouse experiments were conducted on three sweet cherry clonal rootstocks in containers and mist chambers. The effects of applying the auxin transport inhibitor, 2,3,5-triiodobenzoic acid (TIBA) and scopoletin, an indole-3-acetic acid

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(IAA) oxidase enzyme inhibitor, on growth and dry matter partitioning of ungrafted rootstocks and those grafted with ‘Bing’ scions were studied. In the container experiment, the root:shoot ratios and internode lengths of Mazzard (*Prunus avium* L.), Giessen (Gi) 148/1 (*Prunus cerasus* x *Prunus canescens*) and Gi 148/8 (*Prunus cerasus* x *Prunus canescens*) rootstocks were directly related to their potential vigour. Scopoletin applied at 100 ppm reduced internode length but increased girth significantly (p <0.05) in all rootstocks. TIBA at 100 µM, however, had no significant effect on girth increment or internode length. Significant rootstock effects were observed for dry weight partitioning of leaves, new and old shoots, new and old roots. Vigorous Mazzard and Gi 148/1 rootstocks had higher dry matter partitioning into old roots and old shoots but less into leaves or new shoots than the dwarfing Gi 148/8 rootstock. TIBA and scopoletin had no significant effect on dry matter partitioning of different plant parts. The overall dry weight partitioning to leaves, wood and roots of all three rootstocks ranged at about 15 – 22%, 44 – 48% and 30 – 40%, respectively. In the mist chamber experiment, neither rootstock nor inhibitor treatments had any significant effects on root:shoot ratios, internode length or girth increment for the Gi 148/1 and Gi 148/8 rootstocks. There was also no significant rootstock effect on dry matter partitioning in the mist chamber experiment. Scopoletin and TIBA treatments had no significant effect on dry matter partitioning.

Introduction

The growth and dry matter partitioning of fruit trees can be manipulated by growing conditions and management practices such as pruning and training, rootstock, horizontal branch positioning, deficit irrigation, root restriction, growth regulators and forced fruiting (Faust 1989). One of the characteristic features of dwarfing apple rootstocks is their stem branching habits, which in extreme dwarf types display a tendency to become prostrate when allowed to develop naturally (Rogers and Beakbane 1956). Different growth habits were observed in ‘Bing’ sweet cherry trees on rootstocks of varying vigour (Probesting, E.L. and Ophart, D., Dept. of Hort. & LA, Washington State Univ., pers. comm. 1995). ‘Bing’ on the dwarfing Gi 148/8 rootstock has a more spreading form, whereas trees on vigorous Gi 148/1 and Mazzard rootstocks tend to have more upright forms. A tree with spreading growth habit or those that spread due to terminal fruiting on young wood remains small or dwarf. A tree with a weak, shallow or restricted root system may result in a dwarf tree.

Rootstocks have been shown to affect the net assimilation rate of the scion in apple (Gregory 1956). For instance, ‘Cox’s Orange Pippin’ apple scion had higher net assimilation rates over the whole season on a vigorous rootstock than on a dwarfing rootstock. This difference arose largely from photosynthetic activity which continued much later in the autumn on the vigorous rootstock. Atkinson and Wilson (1980) reported a single peak of growth for ‘Merton Glory’ sweet cherry that extended from May until mid-July on F12-1 rootstock, but this period was extended to mid-August on ‘Colt’ rootstock. Beckman (1984) found Mahaleb and Mazzard rootstocks displayed a marked reduction in root growth potential during first leaf expansion, but recovered later in the season.

Total production of dry matter and partitioning of dry matter between fruit and wood varied between and within species (Forshey and Elfving 1989). Heavily fruiting apple trees on dwarfing rootstocks can exhibit very high harvest indices (percentage of total dry weight gain partitioned into fruit). Palmer (1989) reported a harvest index of 65% including root mass, for young dwarf 'Crispin'/M.27 trees. But in mature, heavy-fruiting 'Jonamac'/M.26 trees, the estimated harvest index exceeded 80% including roots (Lakso 1994).

Vegetative growth is as important as reproductive growth in tree fruits, as it provides leaf area for new fruiting sites and maintains tree viability. However, vegetative tissues compete with fruit for photoassimilates. Therefore, a balance between reproductive and vegetative growth should be established. The key to efficient management is to maximize fruit production and minimize unproductive growth (Forshey and Elfving 1989).

Studies have revealed that incorporation of dry matter into different plant parts of the tree follows certain general seasonal patterns (Hansen 1967; Forshey et al. 1983). The growth and distribution of dry matter in apple trees are greatly influenced by root temperatures (Gur et al. 1976a, 1976b, 1976c). The optimum root temperature established for M.2 and M.9 apple rootstock clones range between 13 °C and 25 °C (Gur et al. 1976a). For M.7, however, the optimum temperature is about 30 °C. Root and shoot growth of M.2 and M.9 trees are reduced at 29 °C. Total dry weight and root:shoot ratios also decreased with temperatures above 29 °C. The proportion of dry matter in the roots, but not the leaves decreases at supraoptimal root temperatures (Gur et al. 1976a).

There is a strong competition between vegetative growth and fruiting. Fruiting generally reduced vegetative growth in apple trees (Mochizuki 1962; Verheij 1972). Root growth may be reduced by a light crop, and may be entirely stopped by heavy fruiting (Head 1969; Avery 1970; Dudney and Hadlow 1972).

In the studies reported here, the effects of sweet cherry clonal rootstocks on internode length, girth increment, shoot length and dry weight partitioning of various plant parts were investigated. In addition, experiments were conducted to determine the effects of treatment with auxin transport inhibitor, 2,3,5-triiodobenzoic acid (TIBA) (Botia et al. 1992; Soumelidou et al. 1994) and IAA oxidase inhibitor, scopoletin (Andrea 1952a, 1952b; Imbert and Wilson 1970) on these parameters.

Materials and methods

Container experiment

Rootstocks of Mazzard (*Prunus avium* L.), Giessen (Gi) 148/1 (*Prunus cerasus* x *Prunus canescens*) and Gi 148/8 (*Prunus cerasus* x *Prunus canescens*) were planted in 3-litre containers (15.2 cm diameter x 17.8 cm height) on 16 May 1996 and repotted into 15.6-litre containers (26 cm diameter x 30.5 cm height) 5 weeks later. Peat, pumice and sand in a 6:3:1 ratio was used as a potting mix for both containers. The rootstocks were grown in a greenhouse in a randomized complete block design consisting of four blocks. Each block has one plant of each genotype either treated with scopoletin (7-hydroxy-6-methoxy-2H-1-benzopyran-2-one), TIBA (2,3,5-triiodobenzoic acid) or untreated. These rootstocks were spaced 36 cm apart and grown at air temperatures between 20 °C and 31 °C, at 14 h daylength. The trees were watered every other day and fertilized at 25 days and 105 days after planting with 200 ppm (1g/litre) of a general purpose fertilizer (20:20:20) (Peters, Allentown, Pennsylvania) and supplemented with a soluble trace element mix (0.325 g/litre) (Peters' STEM). In addition, chelated iron and magnesium (Epsom salt, $MgSO_4.7H_2O$) were added at 10 ppm and 24 ppm, respectively. Avid (Abamectin, 0.32 mL/litre) and Enstar II (Kinoprene, 0.79 mL/litre) insecticides were sprayed at 8 weeks after planting to control mites, and Orthene WP (Acephate, 0.79 g/litre) was sprayed at 11 weeks after planting to control thrips.

Two treatments were imposed at 3 months after planting. TIBA (100 µM), an auxin transport inhibitor, was applied as a 3–5 mm wide band of lanolin paste around the trunk at 5 cm above the soil level.

Scopoletin (100 ppm), an IAA oxidase inhibitor, was sprayed on the leaves to run-off. Both treatments were repeated at 2, 4 and 6 days after initial treatment. Photosynthetic active radiation was measured using Licor Model LI-185B (Lincoln, Nebraska). Soil temperature was measured with thermocouples and a digital thermometer (Omega Model HH-52, Stamford, Connecticut). Both measurements were taken on hot, sunny and cool, cloudy days. Trunk girth, shoot length and number of internodes were the growth measurements taken at 0, 3, 6, 9, 12, and 30 days after the initial treatment. At the end of the experiment, each rootstock was separated into leaves, new shoots, old shoots, new roots and old roots. Both fresh and dry weights of these parts were taken. An ANOVAR General Linear Models Procedure of SAS (SAS institute Inc., Cary, North Carolina) was performed on the data. A Least Significant Difference test was used to separate the means at $\alpha = 0.05$ when ANOVAR showed significant differences.

Mist chamber experiment

Dormant bareroot 'Bing' sweet cherry grafted on Gi 148/1 and Gi 148/8 rootstocks were gently washed off sawdust and planted in two identical mist chambers on 9 July 1996 in a completely randomized design. The interior chamber dimension was 1.22 m (W) x 0.74 m (D) x 1.02 m (H) with 10 mist nozzles spaced at 23 cm x 25 cm. Spraying Systems Company (Wheaton, Illinois) No.2 nozzle size was used with an output of 0.21 litre/min at 6.33 kg/cm^2 pressure. The trees were spaced 38 cm x 46 cm apart, and grown at air temperatures between 20 °C and 31 °C, at 14 hours daylength.

About 47% shade was provided with polypropylene shade fabric placed 76 cm above the trees for 14 days after transplanting. Misting was regulated with electronic timers of 1-min duration every 5 min and a pump pressure ranging from 5.62–7.03 kg/cm^2 was maintained. Essential nutrients were incorporated into the stock tank supplying the mist. The nutrients composed of 100 ppm Peters' general purpose fertilizer (20:20:20) supplemented with a soluble trace elements mix (STEM) at 5 g/kg Peters' general purpose fertilizer. Iron chelate and magnesium were also added to this nutrient solution at 4 ppm and 10 ppm, respectively. In addition Avid (Abamectin), Enstar II (Kinoprene) and Orthene WP (Acephate) were sprayed for mite and thrip control, and Bayleton (Triadimefon, 0.37 g/litre) was sprayed for powdery mildew.

Two chemical treatments were applied at 10 weeks after planting. TIBA (100 µM) was applied as a 3–5 mm wide band of lanolin paste around the graft union. Scopoletin (100 ppm) was sprayed on the leaves to run-off. Both treatments were repeated 3 days and 6 days after initial treatment. Light and temperature were measured on hot, sunny and cool, cloudy days as previously described. Similar growth measurements as in the container experiment were taken at 0, 3, 6, 9, 12 and 21 days after initial treatment. The experiment was terminated at 21 days after initial treatment. Each plant was separated, and fresh weights were taken of leaves, new shoots, old shoots, new roots and old roots. Subsequent dry weights of these plant parts were taken after drying in an 80 °C oven. Statistical analysis was performed as in the previous experiment.

Results and discussion

Container experiment

Vigorous Mazzard and Gi 148/1 rootstocks had significantly ($p < 0.05$) higher root:shoot ratios than dwarfing Gi 148/8 rootstock with the ratio of 0.68, 0.55 and 0.42 respectively. These results are not surprising because more root growth relative to shoot growth is expected from more vigorous rootstocks. Gi 148/1 and Gi 148/8 had shorter mean internode lengths than the vigorous Mazzard rootstocks *(Figure 1)*. Shorter internodes are usually associated with more dwarfing rootstocks (Faust 1989).

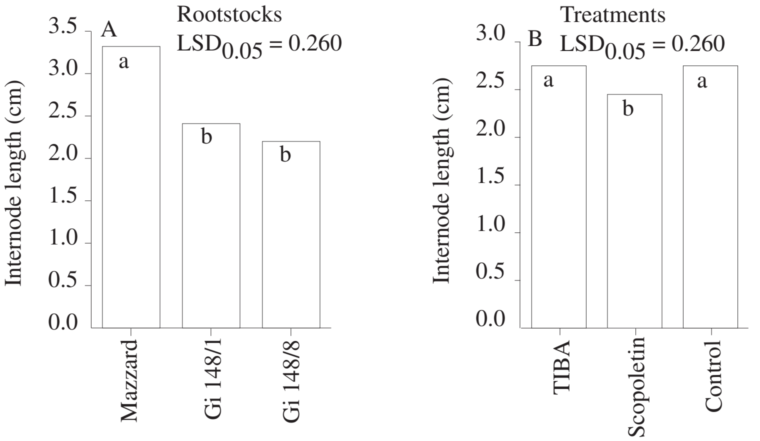

Figure 1. Internode length main effects for three sweet cherry rootstocks (A) and treatment with inhibitors (B)

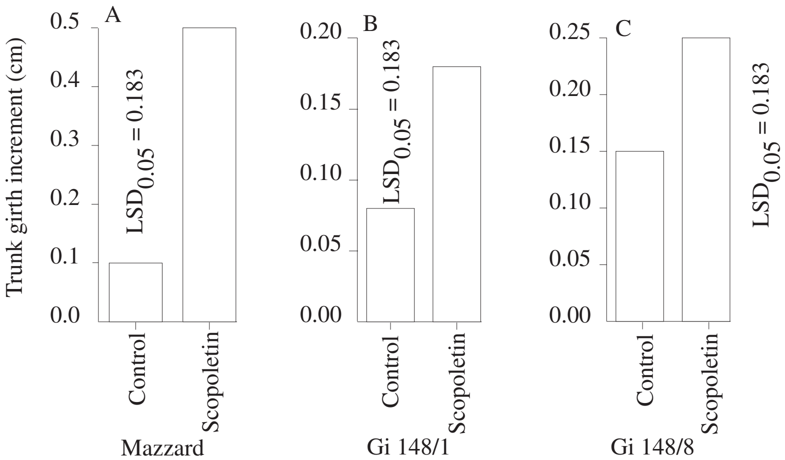

Figure 2. The effects of scopoletin treatment on trunk girth increment of sweet cherry rootstocks grown in containers in a greehouse

Scopoletin reduced mean internode length but increased trunk girth significantly ($p < 0.05$) in sweet cherry clonal rootstocks *(Figure 1* and *Figure 2)*. Scopoletin at 100 ppm promoted IAA oxidase activity in this experiment (Chong 1997). Therefore, auxin levels might have been reduced to a level that stem elongation was inhibited. Cambial activity, however, might have been stimulated at that reduced auxin level resulting in increased trunk girth. TIBA treatment, however, had no significant effect on girth and internode length. Botia et al. (1992) showed that 10 µL of 100 µM TIBA on the cut surface of decapitated plants was able to inhibit IAA polar transport in *Lupin* hypocotyls. Soumelidou et al. (1994) reported that basipetal transport of IAA was blocked by dipping decapitated shoots of M.9 dwarfing and MM.111 semi-vigorous apple rootstocks in only 20 µM TIBA. TIBA concentrations higher than the 100 µM applied may be required to block basipetal transport of IAA, or the uptake of TIBA through the bark was inefficient in sweet cherry clonal rootstocks.

Different rootstocks demonstrated differences in dry matter partitioning.

Vigorous rootstocks had greater partitioning to old roots and old shoots, but less to leaves or new shoots than the dwarfing Gi 148/8 rootstock *(Table 1)*. TIBA and scopoletin had no significant effects on dry weights of leaves, new and old shoots, new and old roots *(Table 2)*. Pooled dry weight partitioning for leaves and shoots (i.e. wood) of sweet cherry rootstocks ranged from 15–22% and 44–48%, respectively. These results were quite similar to the distribution of accumulated dry matter in 8-year-old 'McIntosh'/MM.106 apple trees (Forshey et. al. 1983). They found 19% dry matter accumulated in leaves and 48% in wood.

Mist chamber experiment

No significant differences were observed in dry matter partitioning between Gi 148/1 and Gi 148/8 rootstocks in this experiment *(Table 3)*. This was contrary to results obtained from the container experiment where the vigorous Gi 148/1 rootstock had significantly higher ($p < 0.05$) dry matter partitioning to both new and old roots than the dwarfing Gi 148/8 rootstock. Different root environments in the mist chambers than in the containers, and/or the presence of 'Bing' scion, could have affected dry matter partitioning to roots of these rootstocks. Root temperatures could have affected partitioning of dry matter to the roots. Gur et al. (1976a) showed that dry weight partitioning to roots and shoots were greatest when M.9 rootstock was grown at 25 °C. As root temperature increased to 30 °C, root growth but not leaf growth decreased significantly. Root dry matter production for avocado was generally highest at root temperatures of between 18 °C and 28 °C, and dry matter accumulation in roots was reduced at 32 °C and at 13 °C root temperatures (Yusof et at. 1969; Whiley et al. 1990).

As in the container experiment, scopoletin and TIBA treatments had no significant effect on dry matter partitioning of leaves, new and old shoots, or new and old roots *(Table 3)*. Pooled dry matter partitioning for leaves, and shoots and trunk (i.e. wood) of these two rootstocks were 9% and 50–51%, respectively. Dry matter

Table 1. Dry matter partitioning (%) of Mazzard, Gi 148/1 and Gi 148/8 rootstocks grown in containers and kept in greenhouse

Rootstock	Leaf	New shoot	Old shoot	New root	Old root
Mazzard	15.83b	11.00b	32.75a	16.17b	24.25a
Gi 148/1	16.42b	16.92a	31.25ab	18.17a	17.25b
Gi 148/8	22.25a	19.33a	28.33b	14.92b	15.00c
$LSD_{0.05}$	1.89	2.62	3.40	1.84	1.86

Means with the same letter are not significantly different at $p < 0.05$

Table 2. Effects of TIBA and scopoletin on dry weight (g) of three sweet cherry clonal rootstocks grown in containers in a greenhouse

Treatment	Leaf	New shoot	Old shoot	New root	Old root
Control	29.37	24.25	48.63	26.39	33.29
Scopoletin	27.16	20.69	55.23	27.40	34.62
TIBA	27.81	23.77	50.41	24.47	35.21
$LSD_{0.05}$	6.67	6.80	11.45	5.80	9.12

Scopoletin = 7-hydroxy-6-methoxy-2H-1-benzopyran-2-one or 6-methoxyumbelliferone
TIBA = 2,3,5-triiodobenzoic acid
There was no significant difference between treatment means ($p < 0.05$)

partitioned to leaves in these sweet cherry rootstocks was much less than the partitioning in 8-year-old 'McIntosh'/ MM.106 apple trees (Forshey et al. 1983) and in the container experiment. The growing conditions in the mist chambers may have had some effects on dry matter partitioning.

These studies also showed that rootstocks, and scopoletin and TIBA treatments had no significant effects on root:shoot ratios, mean internode length, or trunk girth increment *(Table 4)*. These inhibitors reduced new shoot growth or increased old shoot growth relative to that of new shoot growth *(Table 3)*. These results were contrary to those of the container experiment. The effects of the 'Bing' scion or the rootstock/scion interaction may have contributed to the differences in growth between rootstocks and the chemical inhibitors.

Conclusion

A balance between vegetative and reproductive growth is the key to efficient

Table 3. Dry matter partitioning (%) of Gi 148/1 and Gi 148/8 rootstocks with 'Bing' scions grown in mist chambers in a greenhouse

	Leaf	New shoot	Old shoot	New root	Old root
Rootstock main effect					
Gi 148/1	8.2	1.57	49.68	3.77	36.8
Gi 148/8	8.6	1.46	48.58	3.99	37.4
$LSD_{0.05}$	2.42	1.21	5.51	2.21	4.45
Treatment main effect					
Control	9.08	2.20	45.22	4.74	38.73
Scopoletin	8.45	1.25	49.72	3.85	36.71
TIBA	7.94	1.27	50.77	3.31	36.70
$LSD_{0.05}$	2.86	1.43	6.51	2.61	5.25

Scopoletin = 7-hydroxy-6-methoxy-2H-1-benzopyran-2-one or 6-methoxyumbelliferone
TIBA = 2,3,5-triiodobenzoic acid
There was no significant difference between treatment means (p <0.05)

Table 4. Growth parameters of Gi 148/1 and Gi 148/8 rootstocks with 'Bing' scions grown in mist chambers in a greenhouse

Rootstock main effect	Root:shoot ratio	Mean internode length (cm)	Trunk girth increment (mm)
Gi 148/1	0.67	1.19	0.12
Gi 148/8	0.71	1.42	0.08
$LSD_{0.05}$	0.14	0.50	0.14
Treatment main effect			
Control	0.78	1.25	0.03
Scopoletin	0.68	1.48	0.18
TIBA	0.66	1.25	0.05
$LSD_{0.05}$	0.17	0.59	0.16

Scopoletin = 7-hydroxy-6-methoxy-2H-1-benzopyran-2-one or 6-methoxyumbelliferone
TIBA = 2,3,5-triiodobenzoic acid
There was no significant difference between treatment means (p <0.05)

management of tree fruits (Forshey and Elfving 1989). Knowing how sweet cherry trees partition dry matter, one could manipulate the desired balance between vegetative and reproductive growth (Faust 1989). Further research is needed in dry matter partitioning of sweet cherry rootstocks of varying vigour at various growth stages. The effects of rootstock scion interaction on dry matter partitioning in sweet cherry also merit further investigation. The prostrate growth habit of dwarf trees could be used as another criteria in screening and selecting potential dwarfing individuals.

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