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Screening of Fig Varieties for Rootstocks Resistant to Soil Sickness

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Summary

Several fig varieties (*Ficus carica* L.) were tested as rootstocks for resistance to soil sickness.

Exp. 1. Scions of 'Masui Dauphine' ('San Piero' sensu Condit, 1955) were grafted on potted rooted cuttings of 21 fig varieties grown for 3 years in a soil with a history of soil sickness. The trees grew poorly and formed root galls induced by root-knot nematodes (*Meloidogyne incognita* Kofoid et White). Scion growth on 'King' and 'Conadrid' stocks was uniformly vigorous, and had less growth inhibition than those on 'Masui Dauphine' (control stock). The root gall indices, which varied with rootstock variety, with 30 % on 'King' as minimum, did not correlate with shoot growth. Therefore, the index fails as an indicator of susceptibility to soil sickness.

Exp. 2. Twenty fig varieties were grown for 1 year in an experimental field with soil sickness and then for 2 more years after grafting with scion of 'Masui Dauphine'. 'Zidi' and 'Biter Abiod' stocks promoted more vigorous scion growth than 'Masui Dauphine' (control stock) did. 'King' was initially weak but became relatively vigorous.

Exp. 3. 'Masui Dauphine' grafted on 'Zidi', 'Biter Abiod', 'King', and own-rooted 'Masui Dauphine' were grown in 6 different farms. The trees grafted on 'Zidi' were vigorous in every field, even those with soil sickness, and with 3-year-old trees, 'Zidi' had no influence on fruit quality, such as Brix and skin color. Thus, we conclude that 'Zidi' is a suitable rootstock for its tolerance to soil sickness.

Key Words: fig rootstock, nematode, soil sickness, tolerance, tree vigor.

Introduction

Soil sickness inhibits the growth of fig trees and seriously reduces the fruit number and size. Fig farmers in Japan are often forced to take costly countermeasures, whereby fig orchards are temporarily changed to other crops (Hirai and Nishitani, 1953). Soil sickness in fig orchards has been a worldwide problem since ancient times, and the root-knot nematode has been recognized as a major cause for the growth inhibition (Condit, 1947b). Nematode-resistant rootstocks have generated interest in overcoming the sick soil problem (Condit, 1947a), specifically, the wild *Ficus* species which have been evaluated for their graft compatibility (Krezdorn and Glasgow, 1970), and parasitization by root-knot nematodes (Hosomi, 1993). Some species are immune, but they are not useful because of their low graft compatibility or low resistance to cold (Condit, 1947a). When commercial varieties of the fig were tested for nematode resistance, some varieties were identified as being semi-resistant (Kawase, 1995). Unfortunately, their growth was inhibited in the sick soil to the extent that they were not suitable as rootstock.

In this study, fig commercial varieties, not native to Japan, were tested as potential rootstock. The growth of potted trees and those growing in the fields with sick soil were compared. The suitability of these varieties was established for rootstocks of the popular Japanese fig 'Masui Dauphine.'

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Materials and Methods

Experiment 1. Screening by using potted trees

Soil samples were collected from fig orchards, exhibiting the symptoms of soil sickness, and were stored in concrete containers with host fig trees. In April of 1990, 1991, 1993, and 1995, 'Masui Dauphine' scions were grafted onto 10 to 20 rooted cuttings of each fig variety listed in Table 1 and onto cuttings of 'Masui Dauphine' (control stock) each year. Each grafted tree was transplanted to a 10-liter unglazed pot, filled with a mixture of sandy soil, Kanuma soil, and vermiculite (1:1:1, v/v/v), and grown for 3 years in the open. In June of the first year, 500 ml of the stored sick soil was added to the bed surface of 5 to 10 pots of each graft combination. Each surface, with or without sick soil, was then covered with 500 ml of peat moss (pH uncontrolled). Fifty-five g of slow-release fertilizer (100-day type $N:P_2O_5:K_2O$ =16:5:10) were applied each June. The trees were watered automatically as required. One shoot of the scion was allowed to elongate per tree; the other shoots

were removed. Every March the shoots were pruned above their 2nd or 3rd node from the base, and their lengths, basal diameters, and dry weights were measured. In March of the first year only, the trees were briefly raised from the pots, and the root growth and the number of root galls formed by nematodes were observed. Root growth was categorized from extremely small (1) to very vigorous (5); root gall formation was rated as 'root gall index' from none (0) to dense (4), according to the legend on Fig. 2 (Smith and Taylor, 1947).

Experiment 2. Screening in the experimental field

A 1.5 a field in which 'Masui Dauphine' trees were growing was covered in 1989 with 100 kg of sick soil. All trees were removed from the field in March 1993. Five rows (each size 11 m × 1.5 m) were then reconstructed in a north-south direction. In April 1993, 1 rooted cutting of each variety in Table 2 and an additional one of 'King' were planted in each of 5 rows, 50cm apart, at random. A total 5 trees per variety and 10 of 'King' were planted. One shoot was elongated per tree and the other shoots were disbudded. In March 1994 each shoot was pruned and measured as in Exp. 1. In April 1994 scions of 'Masui Dauphine' were grafted on each stock and 1 scion shoot per tree allowed to elongate. In March 1995 and 1996 the shoots were pruned and measured as above. Filler trees of the same graft combination were replanted after removing dead trees, but they were not included in the calculations.

Table 1. Relative shoot growth of 'Masui Dauphine' figs grafted onto several rootstocks in the pots with or without sick soil for 3 years.

Rootstock[y]	Type	Imported from	Growing period	Without sick soils			With sick soils[z]		
				Length %[x]	Basal diameter %	Dry weight %	Length %	Basal diameter %	Dry weight %
King	San Pedro	U.S.A.(F)[w]	1991 - '93	110*[v]	109	138*	80*	102**	86**
Conadrid	Common	U.S.A.(F)	1991 - '93	111**	115**	149**	80*	98*	82**
Mavri Aifori	Common	Greece(F)	1995 - '97	137**	112**	169**	71	89	68
San Pietro	Common	Greece(F)	1995 - '97	142**	120**	206**	63	82	60
Capri sp.	Caprifig	U.S.A.(F)	1991 - '93	118**	108*	140**	69	87	60
Difori Kitrina	Common	Greece(F)	1995 - '97	135**	112**	168**	63	80	56
Smirnaiki	Unknown	Greece(F)	1995 - '97	138**	115**	186**	61	89*	54
Biter Abiod	Smyrna	Tunisia(O)	1991 - '93	115**	101	116	66	82	53
Difori Mavri(M.Ts)	Unknown	Greece(F)	1995 - '97	119*	111**	147**	51	83	48
Smirna	Unknown	Greece(F)	1995 - '97	131**	115**	167**	53	79	45
Zidi	Smyrna	Tunisia(O)	1991 - '93	101	105	116	56	79	43
Kalamon	Unknown	Greece(F)	1995 - '97	136**	115**	178**	54	77	42
Difori Prasini	Unknown	Greece(F)	1995 - '97	133**	122**	190**	52	75	42
Violette de Solie's	Common	France(M)	1992 - '94	111	110*	124	49	74	35
Cola Blanche	Common	Greece(F)	1995 - '97	118	105	141	44	70	33
Kimis	Unknoen	Greece(F)	1992 - '94	104	96	92	50	68	32
Perculia Mitilinis	Unknown	Greece(F)	1992 - '94	116*	107	114	49	64	29
Difori Mavri(M.N.)	Unknown	Greece(F)	1995 - '97	119*	113*	139*	34	70	28
Dieredo	Common	U.S.A.(F)	1993 - '95	61	81	45	39	72	26
Prasinosiki Lesvu	Unknown	Greece(F)	1992 - '94	101	93	85	42	62	21
Troiana	Common	Greece(F)	1992 - '94	99	92	88	42	59	20
Masui Dauphine	Common		1991 - '93	100	100	100	64	86	51
Masui Dauphine	Common		1992 - '94	100	100	100	60	78	46
Masui Dauphine	Common		1993 - '95	100	100	100	64	83	49
Masui Dauphine	Common		1995 - '97	100	100	100	58	79	45

[z]Sick soil was added to the bed soil (mixture of sandy soil, Kanuma soil, and vermiculite) in the first year.

[y]Variety names are represented in their countries of export. Variety name of "Capri sp". was unknown. 'Masui Dauphine' was used for control stock.

[x]Mean value of percentage to each on 'Masui Dauphine' grown for respective period without sick soil.

[w]Following alphabet indicate importer:(F), National Institute of Fruit Tree Science;(M), MASUI Farm Ltd.;(O), Osaka Pref. Agr. Res. Ctr.

[v]Mean values are greater than those on respective 'Masui Dauphine' with significant differences at 5% (*) or 1% (**) level.

Experiment 3. Screening rootstocks in commercial fields

In fields A, B, C, D, E, and F in Osaka Prefecture, one-year-old fig trees of 'Masui Dauphine' on the rootstock 'Zidi', 'Biter Abiod', 'King', and own-rooted 'Masui Dauphine' trees were planted in May 1996. The total numbers of planted trees were 7, 7, 3, and 9, respectively. The trees were trained to straight line in the field B and F, and to vase form in the fields A, C, D, and E. Other details of cultivation, such as density of nursery and fertilizing, were left to each farmer, thus, these varied from field to field. The length and basal diameter of every shoot were measured in June and November of 1996 and 1997, and also in August 1998. The volume (V) of each shoot was estimated on the premise that the shoot was a conical column in shape:

$V = \pi \cdot l \cdot (r_1^2 + r_1 \cdot r_2 + r_2^2)/3$,

where l denotes length, r_1 is half of the basal diameter and r_2 is half of the apical diameter of each shoot. Here r_2 is estimated from r_1 by an original regression equation:

$r_2 = 1.4201 \cdot \log_e r_1 + 0.772$,

based on previous measurements of basal and apical diameters (top internode) of 30 other shoots of 'Masui Dauphine.' Reproducibility of the equation is confirmed by the high coefficient of correlation between the estimated volume and fresh weight of another 30 shoots (r=0.99).

In September and October of 1997, the weights, lengths, widths, Brix, and skin color of 10 to 15 fruits per tree in fields A and F were measured.

Results

Experiment 1. Screening by using potted trees

Growth of every shoot and root was inhibited from the first year in the bed with sick soil. Shoot and root growths varied with rootstock varieties, and were positively correlated (Fig. 1). Root-knot nematodes formed galls on every rootstock in the bed with sick soil. The root gall indices also varied with rootstock varieties, from a minimum of 30% on 'King' to a maximum of 75% on 'Biter Abiod'; they varied from 40% to 58% on 'Masui Dauphine' (control stock). However, the root

Table 2. Relative shoot growth of several rootstocks and grafted 'Masui Dauphine' figs in the experimental field with soil sickness.

Root stock[z]	Shoots of rootstocks (1st year)			Shoots of grafted 'Masui Dauphine' (average of 2nd and 3rd years)			Number of trees[y]
	Length %	Basal diameter %	Dry weight %	Length %	Basal diameter %	Dry weight %	alive/tested
Zidi	153*[x]	155**	334**	153**	149**	267**	5/5
Biter Abiod	173*	126	240*	134*	134**	217**	5/5
Houraishi	191**	139**	312**	127	131*	170	5/5
King	109	89	101	121	124*	165	6/10
Capri sp.	159*	131**	250*	96	106	134	4/5
Kimis	121	135*	252	90	108	123	4/5
Prasinosiki Lesvu	91	113	125	110	112	121	4/5
San Pietro	125	113	134	93	111	113	5/5
Troiana	99	110	107	106	115	109	3/5
Difori Mavri(M.Ts)	157*	122*	185*	91	99	102	4/5
Masui Dauphine	100	100	100	100	100	100	5/5
Difori Kitrina	86	96	61	98	111	95	4/5
Difori Mavri(M.N.)	95	110	111	67	82	92	2/5
Violette de Solie's	97	117	127	82	104	89	4/5
Conadrid	103	103	127	89	97	82	5/5
Mavri Aifori	110	103	96	85	95	81	5/5
Kalamon	83	87	76	85	87	67	1/5
Dieredo	32	71	19	58	91	43	5/5
Cola Blanche	75	86	47	46	68	28	5/5
Perculia Mitilinis	70	91	66	42	71	23	5/5
Difori Prasini	70	93	71	45	70	22	5/5

[z]Varieties listed Table 1 (except 'Smirnaiki' and 'Smirna') and 'Houraishi' (traditional variety in Japan) were compared with 'Masui Dauphine' (control stock). Half of the trees of 'King' were imported by National Institute of Fruit Tree Science, the rest by MASUI Farm Ltd.

[y]The number of trees alive after 3 years/planted trees in the first year.

[x]Mean values are greater than those on 'Masui Dauphine' with significant differences at 5% (*) or 1% (**) level.

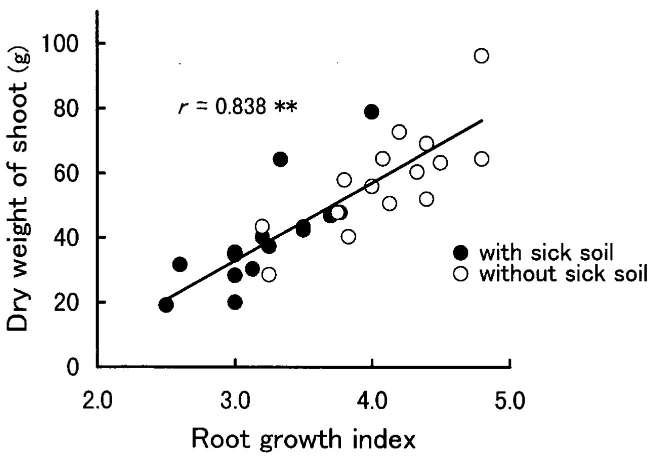

Fig. 1 Relationship between root growth of several rootstocks and shoot growth of grafted 'Masui Dauphine' figs in the pots. Root growth index from extremely small (1) to very vigorous (5). Symbols were given by respective mean data with " ● " and without sick soil " ○ ". **: Signficant at 1% levels by t-test.

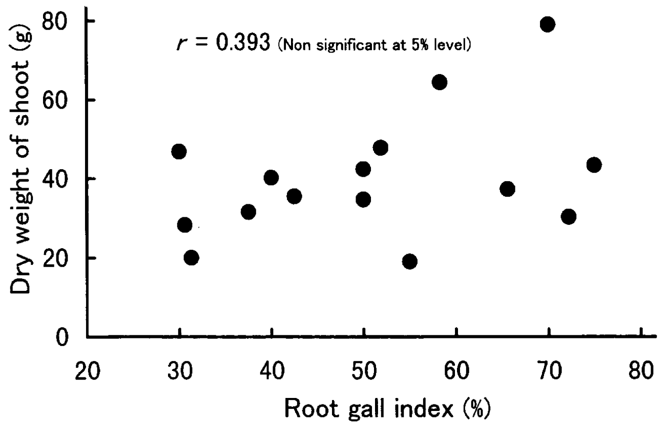

Fig. 2 Relationship between root gall indices of several rootstocks and shoot growth of grafted 'Masui Dauphine' figs in the pots. Symbols were given by the mean data only with sick soil " ● ". No root galls formed without sick soil. Root gall index = 100 × Σ (Infestation category × number of trees in each category)/(4 × all number of trees). Infestation categories show the density of gall:None, rare, sparse, medium, and dense are scored as 0, 1, 2, 3, and 4, respectively.

gall indices did not correlate with shoot growth (Fig. 2). Shoot growth was observed subsequently in the 2nd and 3rd year, and the growth inhibition continued on every rootstock in beds with sick soil. Shoot growth of trees grafted on the limited varieties 'King' and 'Conadrid' for 3 years was more vigorous than those on 'Masui Dauphine' in beds with sick soil, while shoot growth on many varieties was more vigorous in the control bed without sick soil (Table 1).

Experiment 2. Screening in the experimental field

In the first year, the original shoot growth was greater than 'Masui Dauphine' in every parameter measured on 'Zidi,' 'Capri sp.', 'Difori Mavri (M.Ts)', and 'Houraishi', and in some parameters on 'Biter Abiod' and 'Kimis'. Shoot vigor of 'King' and 'Conadrid' was the same as those of 'Masui Dauphine'. For 2 years after grafting, every growth parameter of scion of 'Masui Dauphine' on 'Zidi' and 'Biter Abiod', and basal diameters on 'King' and 'Houraishi' were greater than on 'Masui Dauphine' (control stock). Survival rates of trees on 'King', 'Troiana', 'Kalamon', and 'Difori Mavri (M.N.)' were relatively low; for example, 4 of the 10 trees on 'King' died within the first year (Table 2).

Experiment 3. Screening rootstocks in commercial fields

In fields B and D, all trees grew well; no symptoms of soil sickness were observed, whereas in fields A, C, E, and F, the symptoms of soil sickness were prevalent (Table 3). The total volumes of the shoots were greater on the grafted rootstocks than those on their own-roots. The trees on 'Zidi' were the most vigorous among the three (Table 3). The lengths, widths, and weights of fruits from field F, and the lengths of those from field A were greater on the trees on 'Zidi' than on own-root trees, but fruit quality such as Brix and skin color were unaffected by rootstocks (Table 4).

Discussion

Symptoms of soil sickness can be induced by inoculating the bed with 7% of sick soil (Hosomi and Uchiyama, 1998). In this study, growth inhibition was

Table 3. Shoot volumes of 'Masui Dauphine' figs grafted on 3 fig varieties in fields where the symptoms of soil sickness were observed.

Rootstock	Fields	Planted trees	July-96	Nov.-96	July-97	Nov.-97	Aug.-98
Zidi	A,C,E,F	6	37[z]	303	830**[y]	2538**	3787**
Biter Abiod	A,C,E,F	5	27	150	545*	1600*	2182**
King	A,E	2	52	566	951	2040	1571
Own-rooted	A,C,E,F	7	96	462	96	332	482

[z]Summarized shoot volume (cm^3) per tree. Volume (V) of each shoot was estimated by equations:
$V = \pi \cdot l \cdot (r_1^2 + r_1 \cdot r_2 + r_2^2)/3$, $r_2 = 1.4201 \cdot \log_e r_1 + 0.772$, where l denotes length, r_1 is half of basal diameter of each shoot.
[y]Mean values are greater than own-rooted 'Masui Dauphine' with significant differences at 5% (*) or 1% (**) level.

Table 4. Fruit quality of 'Masui Dauphine' figs grafted on 3 fig varieties in fields A and F.

Field	Rootstock	Length (mm)	Width (mm)	Weight (g)	Brix (%)	Skin color[z]
A	Biter Abiod	70.6b[y]	52.7a	73.4a	14.4a	2.7a
	Zidi	75.0a	54.3a	79.4a	13.7a	2.6a
	King	67.3b	52.2a	74.8a	13.8a	2.3a
	Own-rooted	59.0b	51.4a	73.3a	15.4a	2.7a
F	Biter Abiod	59.1b	45.2b	45.8b	10.3a	2.9a
	Zidi	65.2a	47.7a	53.1a	11.0a	2.6a
	Own-rooted	59.9b	43.8b	45.3ab	11.2a	2.8a

Fruits were sampled from 3-year-old trees in September and October of 1997.
[z]Index value of color chart:R1, R2, R3, R4, and R5, scored as 1, 2, 3, 4, and 5, respectively.
[y]Mean separation within column of each field by Duncan's multiple range test, at 5% level.

induced in potted fig trees (Exp. 1), and when 500ml of inoculated sick soil (5%) was added to the bed soil. Growth inhibition occurred in trees growing in the experimental field (Exp. 2) and in some commercial fields (Exp. 3). Thus, contamination with sick soil influenced growth in every experiment.

Root-knot nematodes formed root galls on every potted tree growing with sick soil. The root gall indices varied with rootstock varieties; 30 % on 'King' was the lowest. A few varieties of the San Pedro type fig to which 'King' belongs, have been reported as semi-resistant to nematodes (Kawase, 1995). The minimum value of the root gall index on 'King' suggests that some nematode resistance exists in this type fig. However, the root gall indices did not correlate with shoot growth (Fig. 2). This suggests that the root gall index does not represent the damage by nematodes, or that other factors are involved in the sick soil. The toxic substances extracted from fig trees, which inhibit plant growth, may be cause for soil sickness of fig orchard (Hatsuda et al., 1960; Hirai and Nishitani, 1951). Hosomi and Uchiyama (1998) also reported that damage by nematodes is slight, so that unknown microorganism may be the basis for growth inhibition in the sick soil. No relationship in this test between root gall index and shoot growth supports these claims. We must, therefore, evaluate the performance of rootstocks by their ability to maintain tree vigor in sick soil regardless of infestation by nematode.

The growth of 'Masui Dauphine' trees on 'King' and 'Conadrid' in the pots, and on 'Zidi' and 'Biter Abiod' in the experimental field was vigorous. The results from commercial fields were similar to those from the experimental field; the trees on 'Zidi' was especially vigorous. These varieties may not be immune to soil sickness because 1) the growth of potted trees on 'King' and 'Conadrid' with sick soil was more dwarfish than that on 'Masui Dauphine' in uncontaminated soil, and 2) the trees on 'Zidi' in the fields with severe soil sickness were more dwarfish than own-rooted 'Masui Dauphine' in an uninfected field. It is clear, however, that these varieties have considerable ability to maintain tree vigor in the sick soil.

Plant growth is obviously enhanced by vigorous rootstocks so that the growth of 'Masui Dauphine' seems to be influenced by the natural vigor of 'Zidi', 'Biter Abiod', 'King', and 'Conadrid'. Potted fig trees grafted on the former two were less vigorous than latter two. The difference is attributed to the lack of soil volume of vigorous rootstock to exhibit their potential. Hence, trees on 'Zidi' and 'Biter Abiod' stocks may be able to compensate for growth inhibition by soil sickness, whenever root growth is not restricted. Further studies are needed to settle the mechanism by which vigor is maintained on these rootstocks. 'King', as a rootstock, enhanced scion growth not only in fields, but also in pots with sick soil so that it may have the ability to maintain vigor in spite of root restriction. The role of nematode resistance in this case is unclear. However, 'King' sometimes died of soil sickness in the nursery so that requires further studies. 'Houraishi', a major variety in Japan, induced vigorous growth of 'Masui Dauphine' scion, but less than did 'Zidi'. The vigorous variety 'Bourjassotte Blanche' has been used as rootstock to promote the growth of 'Bourjassotte Noire' in Spain (Condit, 1947a) but it was not available for this study.

We conclude that among the 21 fig varieties tested as rootstocks, 'Zidi' is the best available one, tolerant to soil sickness. 'Zidi' is known as a vigorous variety in its country of export (Valdeyron and Crossa-Raynaud, 1952) and this characteristic compensates for its susceptibility to soil sickness. The direct influence of rootstock on fruit quality is not probable, but indirectly it confer dwarfishness or excessive succulent growth of shoots that result in small fruit (Hirai, 1966; Hosomi et al., 1989). Succulent growth causes the fruit to become too long in shape (Hosomi et al., 1989). In the commercial fields, the rootstock 'Zidi' promoted relatively long fruit, which we attribute to the succulent growth of the shoots. From our results, we recommend that farmers with uninfected fields plan for future thinning of close-

planted trees or plant fig trees at wider planting distances initially to avoid succulent shoot growth induced by vigorous rootstocks, such as 'Zidi'.

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いや地抵抗性台木としてのイチジク品種の選抜

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摘　要

最近輸入され，本邦での栽培経緯がほとんどなかった21種類のイチジク品種および在来品種'蓬莱柿'について，いや地に対する抵抗性を比較し，主要品種'桝井ドーフィン'の台木としての有効性を検討した．

各品種を台木とする'桝井ドーフィン'苗を，清浄土とこれにいや地土を添加した用土の鉢で3年間育成した．その結果，いや地土を添加した場合いずれも生育が劣り，根にはサツマイモネコブセンチュウの寄生による根こぶが生じた．しかし，生育の抑制程度は台木によって異なり，共台樹に比べて'King'台樹と'Conadrid'台樹で軽かった．また，根こぶ指数(根こぶの発生程度を示す被害指数)も'King'台樹で最小だったが，各種台木の根こぶ指数と樹の生育には相関がなく，根こぶ指数はいや地の感受性の指標とならないと考えられた．

いや地を発生させた試験圃場に各品種を植えて1年間育成し，2年目に'桝井ドーフィン'を接いで合計3年間栽培した．その結果は鉢試験とは異なり，特に'Zidi'台樹，次いで'Biter Abiod'台樹の生育が共台樹より優れていた．'King'の生育もやや優れたが，植え付け初年目の生育は優れず，苗の生存率が劣っていた．'Conadrid'台樹の生育は優れなかった．

鉢試験で生育の優れた'King'と圃場試験で生育の優れた'Zidi'および'Biter Abiod'に接いだ'桝井ドーフィン'苗を大阪府下6カ所の栽培圃場で3年間育成した．その結果，何れも自根苗より生育が優れ，特に，'Zidi'台樹はいや地圃場でも樹勢の低下が少なかった．また，3年生樹の比較において，台木がBrixや果皮色などの果実品質に及ぼす影響は認められなかった．

以上から，いや地での生育抑制を補償できる最も有望な台木として'Zidi'を選定した．