Effects of Rootstock and Interstock on ^{15}N -labeled Nitrogen Absorption and Distribution in 'Kawanakajima Hakuto' Peach Trees

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Summary

The absorption and distribution of applied nitrogen were determined in 4-year-old 'Kawanakajima Hakuto' peach trees grafted on *Prunus persica* (L.) Batsch (PP) and *P. tomentosa* Thunb. (PT) rootstocks and compatible interstock ('Chikuma') / *P. tomentosa* (IS) by using a ^{15}N tracer in the pot experiments. At fruit harvest, 55.7 to 61.3% of the absorbed nitrogen was partitioned to the leaves. The ^{15}N atom% excess in every scion part and the total amount of absorbed ^{15}N were significantly higher in PP and IS than in PT. These results suggest that the use of a compatible interstock, 'Chikuma', improves absorption and upward movement of applied nitrogen, thus it overcomes incompatibility between 'Kawanakajima Hakuto' and *P. tomentosa*.

Key Words: interstock, ^{15}N , nitrogen, peach, *Prunus tomentosa*.

Introduction

Peach trees grafted onto *Prunus tomentosa* Thunb. often decline (Mizutani et al., 1985; Murase et al., 1986; Nakano and Shimamura, 1983; Tsuruta et al., 1985) especially, when Yano et al. (2000, 2002b) grafted 'Kawanakajima Hakuto' peach onto this rootstock. We previously found that the tree decline of 'Kawanakajima Hakuto' grafted on *P. tomentosa* was partly accelerated by the depletion of non-structural carbohydrates at pre-bloom and during the growing season (Yano et al., 2000, 2002a), but also that the use of a compatible interstock improved the dry matter and non-structural carbohydrate levels. Nitrogen and carbohydrate are very important components for maintaining tree vigor. Okamoto et al. (1989) found 'Sanyosuimitsu' trees on *P. persica* rootstock absorbed 3.8 times more nitrogen than those on *P. tomentosa* rootstock.

We compared the absorption and distribution of applied nitrogen by using the ^{15}N tracer method on 'Kawanakajima Hakuto' peach grafted onto seedlings *P. persica* and own-rooted *P. tomentosa* cutting with and without a compatible interstock of 'Chikuma'.

Materials and Methods

Plant materials and growth

P. tomentosa trees, derived by meristem culture in

Sanyo Nouen Corporation (Okayama), were propagated by softwood cutting in 1994. Scions of 'Kawanakajima Hakuto' and 'Chikuma' peaches were grafted on one-year-old *P. tomentosa* rootstock in March 1995; the grafted trees were grown in the field for one year. In March 1996, 'Chikuma' scions were cut 10 cm above the grafted union, and 'Kawanakajima Hakuto' scions were grafted onto them to form a compatible 'Kawanakajima Hakuto' / 'Chikuma' / *P. tomentosa* combination (IS). Simultaneously, 'Kawanakajima Hakuto' scions were cut 10 cm from the grafted union and were allowed to regrow (PT). The trees were dug up in December 1996, their roots trimmed, and transplanted into 80-liter black plastic pots. One-year-old 'Kawanakajima Hakuto' trees, grafted on wild peach (*P. persica* Batsch cv. Ohatsumomo) seedling rootstocks, were planted at the same time (PP). Trees were maintained vegetative until 1998. On January 21, 1999, ^{15}N labeled ammonium sulfate (10 atom%, ISOTEC, USA) was applied to the soil at the rate of 11.1 g (2.4 g N) per tree. All trees were placed in an insect-proof house with a glass roof and irrigated as needed; the drainage solution was recycled for irrigation. Pesticide sprays were applied as required. Data were collected from three trees in each combination. In mid February, the flower buds were thinned at a rate of 4–5 buds per shoot, as flower thinning would cause ^{15}N loss. In late April, the fruit were thinned to approximately 1 per 150 leaves. The number of leaves per tree and branches and the percentages of stunted shoots were counted in mid June, whereas the leaf area was determined in early August. After harvest on August 5, three trees of each combination were dissected and current shoots, old shoots (two- and three-year-

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old shoot), scion trunk, rootstock trunk, large roots (diameter ≥ 10 mm), small to medium roots (10 > diameter ≥ 2 mm), and fine roots (diameter < 2 mm), and their fresh weights were recorded.

¹⁵N analysis

Each organ was collected, washed with water, and dried at 90 °C for 1 hr, followed by 60 °C for 48 hr in a forced-draught oven, and then weighted to calculate their water content. The dried samples were pulverized (100-mesh) in a Swing mill (Kawasakijuko T-100, Japan). Since the mature fruit is sticky, the flesh was freeze-dried and ground to a fine powder (20-mesh) in a coffee mill. To measure the background ¹⁵N amount, the trees of same age without ¹⁵N-labeled fertilizer application (control) grown in plastic pots were collected, and the samples prepared as above. The total

nitrogen and atom percent of ¹⁵N were measured by ANCA-MS (Europa Scientific, U.K.). The ¹⁵N atom% excess, the amount of absorbed ¹⁵N, and the percentage of absorbed ¹⁵N were calculated as follows:

$$^{15}\text{N atom\% excess} = ^{15}\text{N}_{\text{sample}} - ^{15}\text{N}_{\text{BG}}$$

$$\text{The amount of absorbed } ^{15}\text{N} = [\text{DW}] [\text{total N\%}] [^{15}\text{N}_{\text{sample}} - ^{15}\text{N}_{\text{BG}}] / 100 / 100$$

The percentage of absorbed ¹⁵N = [¹⁵N_{absorbed} in the whole tree] 100 / ¹⁵N_{applied}, where total N = total N content (%DW); ¹⁵N_{sample} = ¹⁵N of sample (atom%); ¹⁵N_{BG} = ¹⁵N of non-treated sample (atom%); ¹⁵N_{applied} = the amount of applied ¹⁵N (g/tree); DW = the dry matter weight in each part (g).

Results

There was no difference in total number of leaves among treatments in mid June, but the number of current

Table 1. Numbers of leaves, current shoots and fruit, percentage of stunted shoot, and leaf area in 'Kawanakajima Hakuto' peach trees grafted onto different rootstocks (*P. persica*: PP and *P. tomentosa*: PT) and interstock (IS: 'Chikuma' / *P. tomentosa*) at shoot elongation and harvest periods.

Graft combinations	Mid - June			Early - August			
	No. of leaves (/tree)	No. of current shoots (/tree)	Percentage in stunted shoot / total shoot (%)	No. of leaves (/tree)	No. of current shoots (/tree)	Leaf area ^y (cm ² /leaf)	No. of fruit (/tree)
PP	1185a ^z	138.3a	20.7b	1294a	155.7a	46.5a	6.0a
IS	1167a	131.0a	26.7b	1219a	136.0ab	47.9a	6.7a
PT	979a	91.7b	38.7a	1145a	100.0b	47.4a	5.0a

^z Different letters within columns show significant difference by Duncan's new multiple range test at the 5% level (n = 3).

^y Leaves were collected in middle part of the shoot (30 leaves / tree).

Table 2. Dry matter weight and ¹⁵N detected in various parts of 'Kawanakajima Hakuto' peach trees grafted onto *P. persica* (PP) and *P. tomentosa* (PT) rootstocks and interstock (IS: 'Chikuma' / *P. tomentosa*) at harvest period.

Graft combinations	Total	Scion ^z						Rootstock ^z					S/R ratio ^x
		Total	Leaves	Fruit	Current shoots	Old shoots	Scion trunk	Total	Rootstock trunk	Large roots	Small to medium roots	Fine roots	
Dry matter weight (g)													
PP	2151a ^y	1035ab	291ab	226a	45a	152a	320a	1116a	288a	123a	120a	585a	0.94b
IS	1924ab	1078a	307a	317a	58a	130a	266ab	846b	150b	79a	90a	527a	1.29a
PT	1736b	939b	259b	274a	58a	131a	217b	798b	184b	109a	76a	429a	1.19ab
The amount of total N (g)													
PP	24.8a	11.6a	7.7a	1.5a	0.5a	0.9a	1.0a	13.1a	1.7a	1.3a	1.5a	8.6a	0.92a
IS	24.9a	12.9a	8.5a	1.8a	0.7a	0.8a	0.9ab	12.1a	1.0a	1.1a	1.7a	8.2a	1.09a
PT	22.6a	11.5a	7.5a	1.5a	0.7a	0.9a	0.8b	11.2a	1.2a	1.5a	1.3a	7.0a	1.05a
The amount of absorbed ¹⁵ N (mg)													
PP	109.3a	80.1a	60.9a	10.8a	3.4a	2.6a	2.4a	29.2a	3.1a	2.1a	3.1a	21.0a	2.74b
IS	110.6a	89.0a	67.8ab	12.5a	4.5a	2.2ab	1.9ab	21.7ab	2.1a	1.8a	2.3ab	15.5ab	4.10a
PT	73.6b	57.4b	43.8b	7.6a	3.1a	1.6b	1.3b	16.2b	2.0a	1.7a	1.3b	11.2b	3.54a

^z Scion represents the sum of leaves, fruit, current shoots, old shoots and scion trunk. Rootstock is the sum of the other parts.

^y Different letters within columns show significant difference by Duncan's new multiple range test at the 5% level (n = 3).

^x Ratio of dry matter weight in scion to rootstock part.

shoots was significantly greater in PP and IS than in PT. The percentage of stunted shoot in mid June was significantly higher in PT than in IS and PP. At harvest in early August, PP had the greatest number of current shoots while PT had the lowest; there was no significant difference between IS and PT (Table 1). The numbers of fruit per tree were 6.0, 6.7 and 5.0, and the numbers of leaves per fruit were 221, 183 and 235 for PP, IS and PT, respectively.

Dry matter weight (DW) per tree was the heaviest in PP and the lightest in PT (Table 2). DW of the scion parts of IS was significantly heavier than that of PT. Similar trends were found in the leaves. PP had a significantly heavier DW in the scion trunk than had PT, whereas PP had significantly more DW than IS and PT. The ratios of scion parts to rootstock parts (S/R ratio) on DW basis of IS and PT were higher than that of PP. DW of scion parts was heavier than those of rootstock parts in IS and PT. The amount of total nitrogen (T-N) per tree was slightly higher in PP and IS than in PT, but there was no significant difference among them (Table

2). The amount of absorbed ^{15}N per tree was significantly smaller in PT than in PP or IS (Table 2). A similar relationship for absorbed ^{15}N was present for scion parts. However no significant difference was detected between the rootstocks of IS and PT. The S/R ratio of absorbed ^{15}N in PP was significantly smaller than in the other scion/stock combinations.

T-N concentration in the leaves was highest in PT and lowest in PP (Table 3); those of old shoots and scion trunks showed a similar tendency. T-N concentration of large roots and small to medium roots in IS and PT were significantly higher than in PP but there was no significant difference between PT and IS. However, T-N concentration of fruit was significantly higher in PP than in IS and PT. The ^{15}N atom% excess in the scion parts of PT was significantly lower than those in PP and IS (Table 3). With the exception of the rootstock trunk, there was no significant difference in ^{15}N atom% excess in roots between IS and PT.

In PP, DW percentages of fruit and current shoots were significantly lower than those in IS and PT (Table

Table 3. Total N concentration and ^{15}N atom% excess in various parts of 'Kawanakajima Hakuto' peach trees grafted onto *P. persica* (PP) and *P. tomentosa* (PT) rootstocks and interstock (IS: 'Chikuma' / *P. tomentosa*) at harvest period.

Graft combinations	Leaves	Fruit	Current shoots	Old shoots	Scion trunk	Rootstock trunk	Large roots	Small to medium roots	Fine roots
<i>Total N concentration (% DW)</i>									
PP	2.64c ^z	0.64a	1.16a	0.57b	0.35b	0.58a	1.06b	1.24b	1.48a
IS	2.77b	0.56b	1.21a	0.64ab	0.37ab	0.64a	1.48a	1.85a	1.56a
PT	2.91a	0.53b	1.12a	0.69a	0.40a	0.67a	1.47a	1.73a	1.63a
<i>^{15}N atom % excess</i>									
PP	0.79a	0.73a	0.65a	0.30a	0.24a	0.18ab	0.16a	0.21a	0.24a
IS	0.80a	0.72a	0.65a	0.27a	0.21a	0.23a	0.16ab	0.13b	0.19b
PT	0.58b	0.52b	0.46b	0.19b	0.15b	0.16b	0.11b	0.10b	0.17b

^z Different letters within columns show significant difference by Duncan's new multiple range test at the 5% level (n = 3).

Table 4. Distribution of dry matter and ^{15}N in various parts of 'Kawanakajima Hakuto' peach trees grafted onto *P. persica* (PP) and *P. tomentosa* (PT) rootstocks and interstock (IS: 'Chikuma' / *P. tomentosa*) at harvest period.

Graft combinations	Scion ^z						Rootstock ^z				
	Total	Leaves	Fruit	Current shoots	Old shoots	Scion trunk	Total	Rootstock trunk	Large roots	Small to medium roots	Fine roots
<i>Dry matter distribution (%)^y</i>											
PP	48.1b ^x	13.5b	10.5b	2.1b	7.1a	14.9a	51.9a	13.3a	5.7a	5.6a	27.2a
IS	56.0a	16.0a	16.5a	3.0a	6.7a	13.9a	44.0b	7.8b	4.1a	4.7a	27.4a
PT	54.0ab	14.9ab	15.8a	3.3a	7.5a	12.5a	46.0ab	10.6ab	6.3a	4.4a	24.7a
<i>Distribution of absorbed ^{15}N (%)</i>											
PP	73.3b	55.7a	9.8a	3.1a	2.4a	2.2a	26.7a	2.8a	1.9a	2.8a	19.2a
IS	80.4a	61.3a	11.3a	4.1a	1.9a	1.7a	19.6b	1.9a	1.6a	2.1a	14.0b
PT	78.0a	59.5a	10.3a	4.1a	2.2a	1.7a	22.0b	2.7a	2.3a	1.8a	15.2ab

^z Scion represents the sum of leaves, fruit, current shoots, old shoots and scion trunk. Rootstock is the sum of the other parts.

^y Proportion relative to whole tree.

^x Different letters within columns show significant difference by Duncan's new multiple range test at the 5% level (n = 3).

4). More amount of absorbed ^{15}N was partitioned to the scion parts than to the roots parts in all graft combinations. The percentages of ^{15}N accumulated in the scion parts of PT (78.0%) and IS (80.4%) were significantly higher than that in PP (73.3%). The distribution of absorbed ^{15}N to the leaves was much greater than in the other part in all combinations. The fine roots in PP retained significantly more applied nitrogen than did IS, but there was no significant difference between IS and PT (Table 4).

Discussion

The ^{15}N atom% excess of all tree parts of PP and IS was higher than that of PT reveals a trend that was significant in the individual parts and the entire scion, indicating that more applied nitrogen was absorbed by roots of PP and IS than those of PT. Hence nitrogen absorption was improved by using a compatible interstock. There have been only a few reports about the improvement of nitrogen absorption by the use of an interstock, but the inhibition of nitrogen absorption in incompatible graft combination, but it has been reported for peach-plum (Breen and Muraoka, 1975; Moing and Gaudillère, 1992) and in the dwarfing apple rootstock (Jones, 1971; West and Young, 1988). Nakano and Yamane (1999) reported that the hydraulic connection through the graft union was inhibited in combinations between peach scions and incompatible strains of *P. tomentosa* rootstock which implies that acropetal translocation of nitrogen was also inhibited in incompatible combinations. Moing and Gaudillère (1992) indicated that carbon availability in the roots and nitrogen assimilation by the scions play very important roles in graft incompatibility. We also reported that the use of compatible interstocks improved translocation of photosynthetic products (Yano et al., 2002a). It seems that improving translocation through the graft union by using a compatible interstock overcomes the mobilization of substances at the union.

Mizutani et al. (1996) and Ogata et al. (1989) reported no difference in the nitrogen concentration of leaves between peach trees on *P. persica* and *P. tomentosa* rootstocks. In this experiment, T-N concentration of the leaves was higher in PT than in IS, and lowest in PP (Table 3). However, T-N concentration was within optimum levels regardless of the graft combinations (Tokimoto, 1991). PP and IS had the greater numbers of current shoots than had PT in mid June and at harvest time (Table 1). Furthermore, the percentage of stunted shoot was lower in PP and IS than in PT, indicating that absorbed nitrogen was diluted by vigorous growth in PP and IS.

Previously Yano et al. (2002a) reported that the total DW of PP and IS were greater than that of PT; it was confirmed in this experiment. In particular, DW of PP in older parts, such as the scion trunk and rootstock trunk, was significantly higher than those in PT. However,

there was no significant difference in DW of current-year parts, such as the current shoot and fine roots, between PP and PT. This contradicts the report by Mizutani et al. (1985) who showed that roots of PP grew more vigorously than those in PT. It is possible that the plastic pots used in our experiment might have confined root growth of PP, whereas PT roots being naturally less vigorous would not have been confined as severely as those of PP roots (Yano et al., 2002a).

The greatest amount of absorbed ^{15}N was distributed to the leaves in all combinations reveal that applied nitrogen in winter is transported mainly to the scion, regardless of the graft combination. Sasaki and Sato (1978) also found that ^{15}N applied in winter was detected mainly in scion parts, such as leaves on peach trees.

In conclusion, the use of compatible peach interstock to overcome graft-incompatibility enhances nitrogen allocation to scions and thereby extends the productive lives of dwarf peach trees.

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Literature Cited

- Breen, P. J. and T. Muraoka. 1975. Seasonal nutrient levels and peach/plum graft incompatibility. *J. Amer. Soc. Hort. Sci.* 100: 339-342.
- Jones, O. P. 1971. Effects of rootstock and interstocks on the xylem sap composition in apple trees: effects on nitrogen, phosphorus and potassium content. *Ann. Bot.* 35: 825-836.
- Mizutani, F., H. Tanji, S. Amano, A. Hino, K. Kadoya, J. Watanabe and H. Akiyoshi. 1996. Mineral nutrient elements of peach trees as affected by dwarfing rootstocks. *Bull. Exp. Farm Coll. Agr., Ehime Univ.* 17: 1-11.
- Mizutani, F., M. Yamada, T. Taniguchi, K. Koizumi, A. Sugiura, T. Tomana and K. Kadoya. 1985. Dwarfing effect of *P. japonica* and *P. tomentosa* rootstocks on 'Ohkubo' peach trees. *J. Japan. Soc. Hort. Sci.* 54: 327-335 (In Japanese with English summary).
- Moing, A. and J. P. Gaudillère. 1992. Carbon and nitrogen partitioning in peach/plum grafts. *Tree Physiology* 10: 81-92.
- Murase, S., K. Suzuki and T. Yamazaki. 1986. Studies on dwarfing rootstocks of peach. I. Survival, growth, yield and fruit quality of young peach trees as affected by rootstocks, *Prunus japonica* Thunb., *Prunus tomentosa* Thunb. and *Prunus persica* Batsch. *Bull. Fruit Tree Res. Stn.* A13: 31-49 (In Japanese with English summary).
- Nakano, M. and K. Shimamura. 1983. Growth and yield of peaches on rootstocks of *Prunus tomentosa* and *Prunus persica*. *Mem. Coll. Agr., Okayama Univ.* 61: 67-75.

- (In Japanese with English summary).
- Nakano, M. and T. Yamane. 1999. Direct measure of hydraulic connections in graft union of peaches grafted on *Prunus tomentosa* Thunb. rootstocks. J. Japan. Soc. Hort. Sci. 68 (Suppl. 2): 205 (In Japanese).
- Okamoto, G., Y. Ozeki, K. Shimamura. 1989. A comparative study of mineral absorption by peach trees on *Prunus persica* and *P. tomentosa* rootstock. Environ. Control in Biol. 27: 69-74 (In Japanese with English summary).
- Ogata, T., I. Kataoka, A. Sugiura and T. Tomana. 1989. Effects of several rootstocks on mineral nutrient absorption of peach, nectarine, and plum. J. Japan. Soc. Hort. Sci. 57: 608-614 (In Japanese with English summary).
- Sasaki, I. and Y. Sato. 1978. The time of application and absorption of nitrogen by peach trees using ^{15}N . Bull. Fukushima Hort. Exp. Sta. 8: 17-23 (In Japanese with English summary).
- Tokimoto, T. 1991. Soil management and fertilizing technology in peach orchard. p. 381-403. In: T. Chiba (ed). Soil management and fertilizing technology in orchard. Hakuyusha, Tokyo (In Japanese).
- Tsuruta, T., Y. Yamada, W. Koyaizu and M. Adachi. 1985. Studies on the dwarfing rootstocks for peach. 1. Graft affinity on the combination of rootstock and scion varieties. Bull. Yamanashi Fruit Tree Exp. Sta. 6: 51-56 (In Japanese with English summary).
- West, S. and E. Young. 1988. Effects of rootstock and interstock on seasonal changes in foliar nutrient (N, P, K, Ca) composition of 'Delicious' and 'Golden Delicious' apple. Fruit Varieties J. 42: 9-14.
- Yano, T., H. Inoue, Y. Shimizu and S. Shinkai. 2002a. Dry matter partitioning and carbohydrate status of 'Kawanakajima Hakuto' peach trees grafted onto different rootstocks or with an interstock at pre-bloom period. J. Japan. Soc. Hort. Sci. 71: 164-170.
- Yano, T., H. Inoue, Y. Shimizu, S. Shinkai and M. Ochi. 2002b. Comparison of yield, dry matter distribution and trunk cross-sectional area of 15 peach cultivars grafted onto *Prunus tomentosa* Thunb. rootstocks. Hort. Res. (Japan). 1: 53-58 (In Japanese with English summary).
- Yano, T., S. Shinkai, H. Inoue and K. Moriguchi. 2000. Seasonal changes in starch and soluble sugar contents of two peach cultivars on *P. tomentosa* rootstock showing different degree of tree decline. J. Japan. Soc. Hort. Sci. 69: 711-717 (In Japanese with English summary).

モモ '川中島白桃' 樹における ^{15}N の吸収および分配に及ぼす台木および中間台木の影響

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摘 要

普通台木 (PP 樹), ユスラウメ台木 (PT 樹) や, ユスラウメ台木と親和性の高い中間台木 ('千曲' / PT:IS 樹) に接ぎ木した '川中島白桃' ポット植栽樹を用いて ^{15}N の吸収および分配について調査した. 地上部の全ての部位での ^{15}N atom% excess, および地上部の ^{15}N 吸収量は PP 樹, IS 樹が PT 樹より有意に高かった. 部位別では葉への分配が特に多く, 全吸収量の 55.7-61.3% であった. 以上のことから, 接ぎ木親和性の低い, '川中島白桃' とユスラウメ台木の組合せにおいても, 親和性の高い '千曲' を中間台木として利用することで N 吸収が改善される可能性が示唆された.

り有意に高かった. 部位別では葉への分配が特に多く, 全吸収量の 55.7-61.3% であった. 以上のことから, 接ぎ木親和性の低い, '川中島白桃' とユスラウメ台木の組合せにおいても, 親和性の高い '千曲' を中間台木として利用することで N 吸収が改善される可能性が示唆された.