Distribution of Fall-Applied N in Various Parts of Satsuma Mandarins

Young-Kil Kang,* Zang-Kual U* and Yoeng-Chan Kim*

*College of Agriculture, Cheju National University, Cheju 690-756, Korea

※ This work was supported by the Korean Science and Engineering Foundation (KOSEF) through the Subtropical Horticulture Research Center at Cheju National University, 1999 and published in Korean J. Soil & Fert. 33(5) : 325-332 (2000).

ABSTRACT

To determine the distribution and recovery of fall-applied N in various parts of satsuma mandarins (*Citrus unshiu* Marc.), 19.68 g N tree^{-1} as urea containing 5 atom % ^{15}N and 58 kg K_2O ha^{-1} were broadcast-applied to 11 years old 'Miyagawa Wase' grown at a spacing of 2.7 × 2.7 m on 18 November 1998. Nitrogen, P_2O_5, and K_2O were applied at 104, 308, and 62 kg ha^{-1} on 22 March and N and K_2O at 42 and 83 kg ha^{-1} on 15 June 1999. Two trees were excavated on 15 June and 8 December 1999, respectively. In mid-June, whole tree contained 168.2 g N tree^{-1} of which 11.9, 42.1, 29.7, and 16.3% were in fruits, leaves, stems, and roots, respectively. In early December, total tree N averaged 169.8 g tree^{-1} and fruits accounted for 27.6%, leaves 36.4%, stems 22.8%, and roots 13.2% of total tree N. Regardless of harvest date, N derived from fertilizer was highest in newly developed tissues. In mid June, the tree recovered 18.5% (3.63 g tree^{-1}) of fertilizer N. Fruits accounted for 21.1%, leaves for 50.4%, stems for 21.5%, and roots for 7.9% of fertilizer-derived N in the tree, respectively. In early December, the tree recovered 17.0% of fertilizer N. Fruits contained 39.6%, leaves 40.5%, stems 14.5%, and roots 5.3% of fertilizer-derived N in the tree respectively. Comparing with total tree N, a higher proportion of fertilizer-derived N was allocated to metabolically active tissues while a less proportion to old tissues regardless of harvest date.

Key words: Satsuma mandarin, *Citrus unshiu*, Fall-applied N, Fertilizer-derived N, N distribution, N recovery

Introduction

Nitrogen fertilizer is generally recommended to be applied to satsuma mandarins in early to mid-March, early to mid-June, and late October to early November (just before harvest for early maturing cultivars) in Korea. However, the fall application was often delayed due to delayed harvest and labor shortage. Nitrogen applied in early November was absorbed immediately after the application (Nakahara, 1985). Akao et al. (1978) found that N derived from fertilizer in leaves and fruits was about 11 and 3%, respectively when N was applied at 21 days before harvest (on 18 November). Little amount of N applied in early December was absorbed from December to February when the average soil temperature was below 10℃ and N applied in early December was absorbed in similar way to that applied in March (Nakahara, 1985). Low temperature decreased uptake of N and its translocation to the top (Kato and Kubota, 1982; Kato et al., 1982). A large portion of N absorbed in the winter began to translocate upward after late February (Kato et al., 1982).

At fruit maturity, the recovery of fertilizer N applied in the spring by satsuma mandarin trees ranged from 7 to 29% in Korea depending on N rate and application method and was relatively low (Kang and U, 1998 and 1999; Kang et al., 1998). Kang and U (1998, 1999) and Kang et al. (1998) also reported that at fruit maturity, roots contained 5 to 26%, stems 8 to 32%, leaves 42 to 52%, and fruits 2 to 34% of fertilizer-derived N in the tree, respectively, when N was applied in the spring. There is little information about the distribution and recovery of fertilizer N applied in the summer or fall in Korea. In Japan, satsuma mandarin trees grown in concrete pots or gravel culture recovered 25.1 to 84.2% of fertilizer N depending on the application date, harvest date, and tree age (Akao et al., 1978 and 1981; Kato et al., 1981; Kubota et al., 1976). Japanese researchers also found that the highest recovery of fertilizer N occurred form summer fertilization but the lowest from fall or early spring application. They also reported that fertilizer N was taken up mainly by the new organs, but that there was a large exchange of N between the young parts and the N reserve in the tree (Kato et al., 1982; Kubota et al., 1972a and b). Our objective was to determine the distribution and recovery of fall-applied N in various parts of satsuma mandarin trees grown in a Korean orchard.

Materials And Methods

On 18 November 1998, N at a rate of 27 kg ha^{-1} (19.68 g $tree^{-1}$; 50% of the recommended rate because of shortage of available labeled N) as urea containing 5 atom % ^{15}N and K_2O at a rate of 58 kg ha^{-1} as potassium chloride were broadcast-applied to four 11 years old 'Miyagawa Wase' satsuma mandarins on *Poncirus trifoliata* rootstocks. The satsuma mandarins were grown at a spacing of 2.7 × 2.7 m on a volcanic soil with low nutrient status at Sogwipo, Cheju, Korea at 100 m altitude. Soil test values for surface soil (0 to 10 cm) before the experiment were shown in Table 1. The soil was amended with pulverized dolomitic lime at 2 Mg ha^{-1} and N, P_2O_5, and K_2O as urea, fused phosphate and potassium chloride were applied, respectively, at the recommended rates (104, 308, and 62 kg ha^{-1}) on 22 March 1999. Nitrogen and K_2O as urea and potassium chloride were applied at 42 and 83 kg ha^{-1}, respectively, on 15 June 1999.

Two trees were excavated on 15 June and 8 December 1999, respectively and divided into various parts as shown in Table 2 and 3. After fresh weight of various parts was measured at each harvest, about 0.2 kg of various tree parts were sampled and dried at 70℃ to a constant weight in a forced draft oven. The dried subsamples were ground to pass a 1.0- and 0.4-mm screen for total N and ^{15}N determinations, respectively. Total N was determined by using Kjedahl method. The ^{15}N percent was measured with an isotope-ratio mass spectrometer (SIRA II VG-Isotech, England).

The percentage of N derived from fertilizer (%NDFF) and the recovery of fertilizer N (fertilizer use efficiency) were calculated as

NDFF (%) = plant ^{15}N atom %-0.366 × 100/fertilizer ^{15}N atom %-0.366

Recovery of fertilizer (%) = plant total fertilizer N × NDFF/fertilizer rate

Results and Discussion

1. Distribution of dry matter

The top and roots constituted 75 and 25% of whole tree dry weight (13,302 g $tree^{-1}$) in the 12 years old tree evacuated on 15 June (June harvest) (Table 2). Fruits including shed fruits, leaves, and stems

Table 1. Chemical properties of surface soil (0~10 cm) before the experiment

pH (1:5)	O.M. (g kg^{-1})	T-N (g kg^{-1})	Av. P_2O_5 (mg kg^{-1})	Exchangeable cations (cmol· kg^{-1})			EC (dS m^{-1})
				Ca	Mg	K	
3.9	129	4.6	81	0.6	0.1	0.3	0.88

Table 2. Dry weight and total N content and accumulation in various parts of 12 years old satsuma mandarin trees[1)] in mid-June, 1999

Parts of tree	Dry weight		Total tree N		
	(g tree⁻¹)	(% of total)	(% of dry wt)	(g tree⁻¹)	(% of total)
Fruits	863±64[2)]	6.5±0.71	2.30±0.110	19.9±2.41	11.9±1.89
Young	740±57	5.6±0.63	2.25±0.134	16.7±2.27	10.0±1.74
Shed	123±7	0.9±0.08	2.62±0.028	3.2±0.14	1.9±0.16
Leaves	2882±129	21.7±0.20	2.46±0.027	70.9±2.39	42.1±0.22
Spring frush	742±71	5.6±0.33	2.76±0.032	20.4±1.71	12.1±0.54
1-year old	1848±66	13.9±0.99	2.40±0.018	44.3±1.90	26.4±2.16
Over 2-yr old	293±124	2.2±0.85	2.09±0.005	6.1±2.58	3.6±1.39
Stems[3)]	6241±171	46.9±0.40	0.80±0.047	50.0±4.27	29.7±1.38
Spring frush	156±12	1.2±0.04	1.50±0.010	2.3±0.16	1.4±0.04
1-year twigs	427±51	3.2±0.50	1.48±0.061	6.3±0.49	3.7±0.44
Green twigs	901±7	6.8±0.30	1.02±0.157	9.2±1.34	5.5±0.58
Large twigs	701±103	5.3±0.96	0.70±0.020	4.9±0.86	2.9±0.62
Branches	821±202	6.2±1.74	0.71±0.055	5.7±0.97	3.4±0.71
Scaffolds	2750±150	20.7±0.39	0.67±0.060	18.5±2.64	11.0±1.14
Trunk	487±372	3.7±2.67	0.60±0.048	3.1±2.45	1.8±1.39
Roots[4)]	3316±240	24.9±0.91	0.83±0.010	27.4±2.30	16.3±0.73
Stock	1020±57	7.7±0.70	0.70±0.020	7.2±0.60	4.3±0.52
Large	1251±23	9.4±0.16	0.70±0.001	8.8±0.15	5.2±0.11
Medium	662±167	5.0±0.08	0.90±0.012	5.9±1.42	3.5±0.71
Small	240±55	1.8±0.35	1.29±0.066	3.1±0.55	1.8±0.26
Fine	143±52	1.1±0.35	1.81±0.107	2.5±0.78	1.5±0.41
Whole tree	13302±476	100.0±0.00	1.26±0.004	168.2±6.55	100.0±0.00

[1)] Nitrogen was applied at a rate of 19.7 g tree⁻¹ as labelled urea on 18 November 1998 and at a rate of 75.8 g tree⁻¹ as non-labelled urea on 22 March 1999

[2)] Values are means±standard errors for two trees

[3)] Green twigs, larger twigs, scaffolds and trunk were 3 to 8, 9 to 20, 21 to 30, 31 to 50 and above 60 mm in diameter, respectively

[4)] Stock, large, medium, small, and fine roots were above 90, 21 to 65, 11 to 20, 2 to 10 and below 2 mm in diameter, respectively constituted 6.5, 21.7, and 46.9% of whole tree dry weight, respectively. The dry matter of current shoots was 1,761 g tree^{-1} and accounted for 17.6% of the top dry matter. The spring flush leaves constituted 25.7% of the total leaf dry weight and the spring flush twigs 2.5% of the whole stem dry weight.

The top accounted for 82.4% of whole tree dry weight (17,082 g tree^{-1}) on 8 December (December harvest) (Table 3). Fruits including shed fruits, leaves, stems, and roots constituted 30.3, 14.7, 37.3, and 17.6% of the whole tree dry weight. Between 15 June and 8 December, the whole tree dry weight increased 28.4% because of increase in fruit weight by six times. The whole stem dry weight increased slightly while leaf and root dry weight decreased 12.6 and 9.3%, respectively. The decrease in leaf dry weight between the two harvests seemed to be due to leaf abscission and the decrease in root dry weight might be due to the difference between the trees evacuated. The spring flush leaves constituted 29.2% of the total leaf dry weight and the spring flush twigs 2.2% of the whole stem dry weight. Summer and fall growth flushes did not occur on the trees harvested in early December because of on-year trees.

2. Content, accumulation and distribution of total N

In the June harvest, the highest total N content was found in fruits and leaves in which N content ranged from 2.09 to 2.76% (Table 2). The total N content of stems and roots ranged from 0.60 to 1.50% and from 0.70 to 1.81%, respectively. In the December harvest, the spring flush and old leaves also had the highest total N content with 2.76 and 2.33%, respectively (Table 3). The total N content in the peel and pulp of mature fruits averaged 0.84 and 0.90%, respectively. The total N content of stems and roots ranged from 0.44 to 1.38% and from 0.57 to 1.47%, respectively. The total N content between the two harvests did not change in leaves but declined in fruit, stems, and roots. This results resemble findings by previous researches and suggest a strong N demand by metabolically active tissues (Akao et al., 1978; Kato and Kubota, 1982; Kato et al., 1981 and 1982; Kubota et al., 1972a and b, 1976; Mooney and Richardson, 1992).

In the June harvest, whole tree contained 168.2 g N tree^{-1} of which 11.9, 42.1, 29.7, 16.3% were in fruits, leaves, stems, and roots, respectively. The spring flush leaves constituted 28.8% of the total leaf N and the spring flush twigs 4.6% of the total stem N. In the December harvest, total tree N averaged 169.8 g tree^{-1}. Fruits contained 27.6%, leaves 36.4%, stems 22.8%, and roots 13.2% of the total tree N. Between 15 June and 8 December, total N in fruits increased 2.3 times while total N decreased 12.8% in leaves, 22.6% in stems, and 17.9% in roots indicating that total N in leaves, stems, and roots was translocated to fruits. There was no difference in total tree N accumulation between the two harvests. This was probably due to abscissed leaves and fruits not collected. The spring flush leaves constituted 32.8% of total leaf N and the spring flush twigs 4.9% of the total stem N. The proportion of leaf total N in spring flush leaves in the December harvest increased as a result of abscission of old leaves because total N content of old leaves did not significantly decrease but the leaf dry weight 17.0% comparing with the June harvest.

Leaves accounted for higher proportion of total tree N as shown in previous studies (Kang and U, 1998 and 1999; Kang et al., 1998; Kato and Kubota, 1982; Kato et al., 1981 and 1982; Kubota et al., 1976), indicating that leaves play a greater role as N reserve in the tree. This result and previous foundings suggest that reducing abscission of leaves in the winter should be an important management practice for well-balanced spring growth flush.

3. Percentage, uptake and distribution of fertilizer-derived N and recovery of fertilizer N

In the June harvest, N derived from fertilizer

Table 3. Dry weight and N content and accumulation in various parts of 12 years old satsuma mandarin trees[1)] in early December, 1999

Parts of tree	Dry weight		Total tree N		
	(g tree^{-1})	(% of total)	(% of dry wt)	(g tree^{-1})	(% of total)
Fruits	5182±223[2)]	30.3±2.61	0.90±0.039	46.8±0.01	27.6±1.96
Peel	1850±106	10.8±1.09	0.84±0.027	15.6±0.40	9.2±0.89
Pulp	3258±138	19.1±1.63	0.90±0.033	29.2±0.16	17.2±1.32
Shed[3)]	75±21	0.4±0.10	2.70±0.015	2.0±0.55	1.2±0.24
Leaves	2518±162	14.7±0.32	2.46±0.016	61.8±4.38	36.4±0.01
Spring frush	735±123	4.3±0.54	2.76±0.027	20.3±3.20	12.0±1.05
Old	1777±35	10.4±0.24	2.33±0.016	41.5±1.11	24.4±1.08
Shed	5±4	0.0±0.02	1.97±0.153	0.1±0.07	0.1±0.04
Stems[4)]	6373±389	37.3±0.68	0.61±0.003	38.7±2.14	22.7±0.35
Spring frush	139±17	0.8±0.06	1.38±0.002	1.9±0.23	1.1±0.05
1-year old twigs	400±3	2.3±0.12	1.17±0.050	4.7±0.16	2.8±0.10
Green twigs	1013±3	5.9±0.23	0.77±0.023	7.8±0.21	4.6±0.45
Larger Twigs	941±44	5.5±0.50	0.55±0.02	5.2±0.43	3.1±0.47
Branches	1506±273	8.8±1.22	0.52±0.010	7.8±1.57	4.6±0.60
Scaffolds	1590±194	9.3±0.74	0.50±0.006	7.9±0.87	4.7±0.19
Trunk	784±51	4.6±0.50	0.44±0.023	3.4±0.04	2.0±0.17
Roots[5)]	3009±404	17.6±1.61	0.75±0.08	22.5±5.48	13.2±2.30
Stock	1052±72	6.2±0.68	0.57±0.054	6.0±0.15	3.5±0.16
Large	949±164	5.6±0.72	0.63±0.025	6.0±1.26	3.5±1.50
Medium	381±74	2.2±0.34	0.81±0.002	3.1±0.61	1.8±0.23
Small	486±161	2.8±0.82	1.10±0.126	5.4±2.32	3.2±0.15
Fine	141±77	0.8±0.42	1.47±0.009	2.1±1.14	1.2±0.59
Whole tree	17082±732	100.0±0.00	0.99±0.028	169.8±24.01	100.0±0.00

1) Nitrogen was applied at a rate of 19.7 g tree^{-1} as labelled urea on 18 November 1998 and at rates of 75.8 and 30.6 g tree^{-1} as non-labelled urea on 22 March and 15 June 1999, respectively

2) Values are means±standard errors for two trees

3) Shed fruits and leaves were collected on 8 December and 15 June, respectively

4) Green twigs, larger twigs, scaffolds and trunk were 3 to 8, 9 to 20, 21 to 30, 31 to 50 and above 60 ㎜ in diameter, respectively

5) Stock, large, medium, small, and fine roots were above 90, 21 to 65, 11 to 20, 2 to 10 and below 2 ㎜ in diameter, respectively

(NDFF) applied in the fall of 1998 was 3.9% in young fruits, ranged from 2.0 to 4.0% in leaves, 0.9 to 4.1% in stems, and from 0.6 to 2.6% in roots (Table 4). In the December harvest, NDFF in peel and pulp was 3.0 and 2.7%, respectively (Table 5). Between 15 June and 8 December, an average NDFF decreased from 2.6 to 2.2% in leaves, from 1.6 to 1.3% in stems, and from 1.0 to 0.8% in root probably because of an increase in the absorption of non-labeled N applied in the spring and summer of 1999. Regardless of harvest date, the NDFF was highest in newly developed tissues as shown in previous studies (Akao et al., 1978; Kubota et al., 1972a and b, 1976; Mooney and Richardson, 1992) indicating that recently absorbed N is preferentially allocated to younger tissues.

Table 4. Nitrogen derived from fertilizer (NDFF), and uptake and recovery of fertilizer N in various parts of 12 years old satsuma mandarin trees1) in mid-June, 1999

Parts of tree	NDFF (%)	Fertilizer N		Recovery of fertilizer N (%)
		(g $tree^{-1}$)	(% of total)	
Fruits	3.84±0.038[2)]	0.77±0.100	21.1±1.29	3.89±0.508
Young	3.86±0.142	0.64±0.064	17.7±1.65	3.26±0.325
Shed	3.84±0.960	0.12±0.036	3.4±0.36	0.63±0.183
Leaves	2.60±0.687	1.83±0.425	50.4±2.24	9.30±2.160
Spring frush	4.00±0.406	0.81±0.014	22.3±3.97	4.12±0.074
1-year old	2.04±0.812	0.92±0.399	25.3±6.41	4.68±2.026
Over 2-yr old	2.08±1.072	0.10±0.012	2.7±0.20	0.51±0.061
Stems[3)]	1.61±0.522	0.78±0.192	21.5±1.25	3.97±0.976
Spring frush	4.08±0.625	0.09±0.008	2.6±0.28	0.48±0.042
1-year twigs	2.60±0.445	0.17±0.041	4.6±0.27	0.84±0.207
Green twigs	2.04±0.496	0.18±0.018	5.0±0.46	0.92±0.093
Large twigs	1.40±0.491	0.07±0.036	2.0±0.64	0.37±0.184
Branches	1.25±0.471	0.08±0.039	2.1±0.70	0.38±0.197
Scaffolds	1.01±0.465	0.18±0.059	4.8±0.74	0.89±0.301
Trunk	0.87±0.385	0.02±0.009	0.5±0.36	0.09±0.048
Roots[4)]	1.04±0.137	0.29±0.062	7.9±3.31	1.46±0.313
Stock	0.59±0.101	0.04±0.011	1.2±0.28	0.22±0.055
Large	0.86±0.332	0.08±0.030	2.1±0.48	0.38±0.154
Medium	1.02±0.352	0.07±0.035	1.8±1.36	0.33±0.179
Small	1.49±0.004	0.05±0.008	1.3±1.28	0.23±0.042
Fine	2.59±0.856	0.06±0.001	1.6±0.08	0.30±0.007
Whole tree	2.18±0.494	3.67±0.688	100.0±0.00	18.46±3.497

[1), 2), 3), 4)] See Table 2 for explanation

Table 5. Nitrogen derived from fertilizer1) (NDFF), and uptake and recovery of fertilizer N in various parts of 12 years old satsuma mandarin trees in early December, 1999

Parts of tree	NDFF (%)	Fertilizer N		Recovery of fertilizer N (%)
		(g tree $^{-1}$)	(% of total)	
Fruits	2.84±0.046[2]	1.33±0.021	39.6±4.72	6.74±0.108
Peel	2.95±0.006	0.46±0.011	13.8±2.19	2.34±0.055
Pulp	2.67±0.041	0.78±0.008	23.2±2.91	3.95±0.039
Shed[3]	4.40±0.000	0.09±0.024	2.7±0.38	0.45±0.124
Leaves	2.17±0.227	1.35±0.236	40.5±1.69	6.88±1.198
Spring frush	3.11±0.21	0.62±0.057	18.6±0.79	3.17±0.289
Old	1.75±0.382	0.73±0.178	21.8±2.47	3.71±0.905
Shed	0.92±0.169	0.00±0.001	0.0±0.02	0.01±0.004
Stems[4]	1.25±0.218	0.49±0.111	14.5±1.41	2.47±0.563
Spring frush	3.00±0.078	0.06±0.008	1.7±0.02	0.29±0.042
1-year old twigs	2.15±0.356	0.10±0.020	3.0±0.20	0.51±0.102
Green twigs	1.59±0.310	0.12±0.021	3.7±0.14	0.63±0.106
Larger Twigs	1.04±0.112	0.05±0.001	1.6±0.18	0.27±0.007
Branches	0.99±0.323	0.08±0.041	2.5±0.91	0.42±0.207
Scaffolds	0.55±0.068	0.04±0.010	1.3±0.13	0.22±0.052
Trunk	0.73±0.284	0.02±0.009	0.7±0.19	0.13±0.048
Roots[5]	0.76±0.158	0.18±0.077	5.3±1.62	0.91±0.391
Stock	0.69±0.211	0.04±0.014	1.2±0.25	0.21±0.073
Large	0.69±0.193	0.04±0.020	1.2±0.44	0.22±0.103
Medium	0.73±0.145	0.02±0.009	0.7±0.18	0.12±0.045
Small	0.72±0.058	0.04±0.020	1.2±0.44	0.20±0.100
Fine	1.54±0.156	0.03±0.014	0.9±0.32	0.15±0.070
Whole tree	1.97±0.123	3.35±0.445	100.0±0.00	17.00±2.260

1),2),3),4),5) See Table 3 for explanation

In the June harvest, tree recovered 18.5% (3.67 g tree $^{-1}$) of the labeled N applied (19.68 g tree $^{-1}$) in the fall of 1998. Fruits accounted for 21.3%, leaves for 50.4%, stems for 21.5%, and root for 7.9% of fertilizer-derived N in the tree. The spring flush leaves constituted 44.3% of total leaf fertilizer N and 11.5% of total stem fertilizer N. Nakahara (1985) reported that spring flush leaves of 20 years old satsuma mandarin contained 51% of total leaf fertilizer N in July. In the December harvest, tree recovered 17.0% (3.35 g tree $^{-1}$) of fertilizer N. Fruits accounted for 39.7%, leaves for 40.3%, stems for 14.4%, and roots for 5.1% of fertilizer-derived N in the tree. Between 15 June and 8 December, fertilizer-derived N increased 72.7% in fruits but decreased 26.2% in leaves, 34.7% in stems, and 37.9% in roots indicating that fertilizer-derived N in leaves, stems and roots was reallocated to fruits. Compared with the June harvest, slightly less fertilizer N was recovered probably because of shed leaves and fruits not collected. The spring flush leaves constituted 45.9% of the total leaf fertilizer N and the spring flush twigs 12.2% of the total stem fertilizer N.

Comparing with total tree N, a higher proportion of fertilizer N was allocated to metabolically active tissues (fruits, and spring flush leaves and twigs) while a less proportion of fertilizer N to old tissues regardless of harvest date. In the June and December harvests, spring flush leaves contained 12.1 and 11.9% of total N in the tree respectively, but 23.1 and 18.7% of fertilizer-derived N in the tree, respectively. This pattern held with fruits and spring flush twigs. The results of this study are comparable with those in the literature in that young, metabolically active tissues benefited greatly from newly absorbed N (Akao et. al., 1978; Kato et. al., 1981 and 1982; Kubota et al., 1976).

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가을에 시용한 질소의 온주밀감 수체 부위별 분포

강영길* · 유장걸* · 김용찬*

1998년 11월 18일에 2.7 × 2.7 m 거리로 재식된 11년생 궁천조생온주 4주에 5 atom % ^{15}N 요소로 19.68 g 주$^{-1}$의 N, 58 kg ha^{-1}의 K_2O을 시용하였고, 1999년 3월 22일에 104, 308, 62 kg ha^{-1}의 N, P_2O_5, K_2O를, 6월 12일에 42 and 83 kg ha^{-1}의 N, K_2O를 시용하여 재배한 후 1999년 6월 15일과 12월 8일에 각각 2주씩 굴취·해체하여 전질소 및 가을시용질소의 함유량의 수체 부위별 분포 등을 조사하였다. 과실, 잎, 줄기, 뿌리에의 전질소 함유량의 분포비율은 6월 굴취 때에 각각 주당 전질소 총함유량(168.2g)의 11.9, 42.1 29.7, 16.3%이었고, 12월 굴취 때에 각각 주당 전질소 총함유량(169.8g)의 27.6, 36.4, 22.8, 13.1%이었다. 수체 질소 중 가을시용질소에서 유래된 질소의 비율은 두 굴취 시기 모두 새로 발생된 기관에서 현저히 높았다. 6월 굴취 때의 가을시용질소 회수율은 18.5%(3.67g 주$^{-1}$)이었고, 주당 가을시용질소 총함유량의 21.1, 50.4, 21.5, 7.9%가 각각 과실, 잎, 줄기, 뿌리에 분포되어 있었다. 12월 굴취 때의 가을시용질소 회수율은 17.0%(3.35g 주$^{-1}$)이었고 가을시용질소 총함유량의 39.6, 40.5, 14.5, 5.3%가 각각 과실, 잎, 줄기, 뿌리에 분포되어 있었다. 전질소에 비하여 두 시기 모두 가을시용질소에서 유래된 질소는 대사적으로 활발한 조직에 보다 많이 축적된 반면 오래된 조직에는 보다 적게 축적되었다.

Key words : Satsuma mandarin, *Citrus unshiu*, Fall-applied N, Fertilizer-derived N, N distribution, N recovery

* 제주대학교 농과대학 (College of Agriculture, Cheju National University, Cheju 690-756, Korea)

※ 이 논문은 한국과학재단 지정 제주대학교 아열대원예산업연구센터의 1999년도 연구비 지원에 의해 수행된 결과임