A case study on leaching characteristics of *Quercus glauca* leaves in Southern Kyusyu stream water

Hirokazu Kitamura

Laboratory of Landscape Conservation, Minami-Kyushu University, Miyakonojyo, Miyazaki 885-0035, Japan

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To identify leaching characteristics from initial decomposition of evergreen leaf litter, well washed and dried new and old leaves of *Q. glauca* were submerged in invertebrate-free stream water with or without air supply for a total of four treatments: old leaves with aeration; old leaves without aeration; new leaves with aeration and new leaves without aeration. 1, 5, 10, 20 and 30 days after submersion, weight loss rates in leaves, the concentrations of ions, total carbon (TC) and total nitrogen (TN) of the water were measured.

The leaves in aerated water lost 4-7% of the initial weight on the first day after submergence and weight loss slowed in treatments without aeration, and overall weight loss from evergreen leaves was less than a quarter of that from deciduous leaves. TC and TN concentrations increased for the first 5 to 10 days and non-aerated treatments were nearly constant, whereas TC and TN concentrations continued to rise after the 10th day in aerated treatments. There was a significant correlation between TC and TN concentrations and weight loss rate. It was inferred that the tough outer surfaces of evergreen leaves (e.g., cuticle) may delay leaching and subsequent weight loss in leaves until the outer layer of the epidermis, which consists of cutin, breaks down in water. The rate of decomposition of leaf litter in the water may be increased by abrasion of leaf surfaces.

The most dominant cation was K^+, accounting for around 70% of all cations in aerated sample waters. By day 30, NH_4^+, K^+, Mg^{2+} and Cl^- concentration were more than two times higher than the initial concentrations in all treatments. Based on the results of the leaching experiment in the present study, biomass contribution to stream water composition, i.e. through leachate from leaf litter, is important.

Key words: stream water quality, leaching, *Quercus glauca*, ions, TC.

1. INTRODUCTION

Allochthonous material, such as leaves, is a primary energy source for secondary consumers in small streams. Organic matter is decomposed by a variety of physical, chemical and biological processes[1]. After leaves fall into streams, soluble chemicals are leached from plant tissue, and leaf tissues are colonized by microbes, fragmented by mechanical abrasion and invertebrate activity. The in-stream processing of this organic material produces dissolved organic matter (DOM)[19] and inorganic nutrients[2, 18].

As considerable quantities of allochthonous material enter lotic ecosystems from riparian forests[6], substances derived from the decomposition of leaf litter may have an important effect on stream water quality. Pioneering studies[9, 20] have suggested that leaf litter from different tree species produce markedly diverse leachates and have different effects on the chemical characteristics of stream water. Some research has studied the physical degradation of leaf litter, such as weight loss rates[14, 16] or chemical changes associated with deciduous leaf litter degradation in streams[11, 13, 15]. However, few studies have examined leachates from evergreen leaf litter and the effect on stream water quality during initial decomposition.

The purpose of the present study was to identify leaching characteristics from initial decomposition of *Quercus glauca* leaf litter. This species is an evergreen that is dominant in the riparian zone of temperate streams in Southern Kyushu, Japan and represents a substantial source of allochthonous material to streams.

2. METHODS

All leaves were collected from the riparian zone of the Takeo River in Saito City, Miyazaki Prefecture. The Takeo, a tributary of the Hitotsuse River, ranges from 100 to 600 m in elevation and originates in the Southern Kyushu Mountains (Fig.1). For the present study, all leaves were collected from the branches at 2 to 4 m height from the ground surface of one tree (*Quercus glauca*), which had been growing on the sunny and non-fertilized alluvial-plain of the river. All leaves were sun leaves. Leaves picked from the tip of branches of the tree were considered to be new leaves and had been growing since March 2010 and still appeared yellow-green due to the relatively

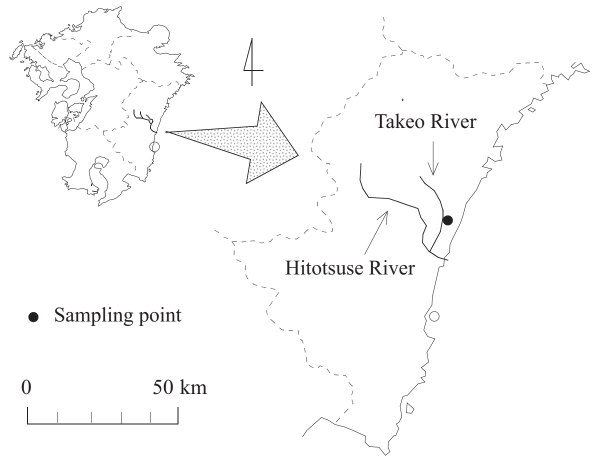

Fig. 1. Investigated site

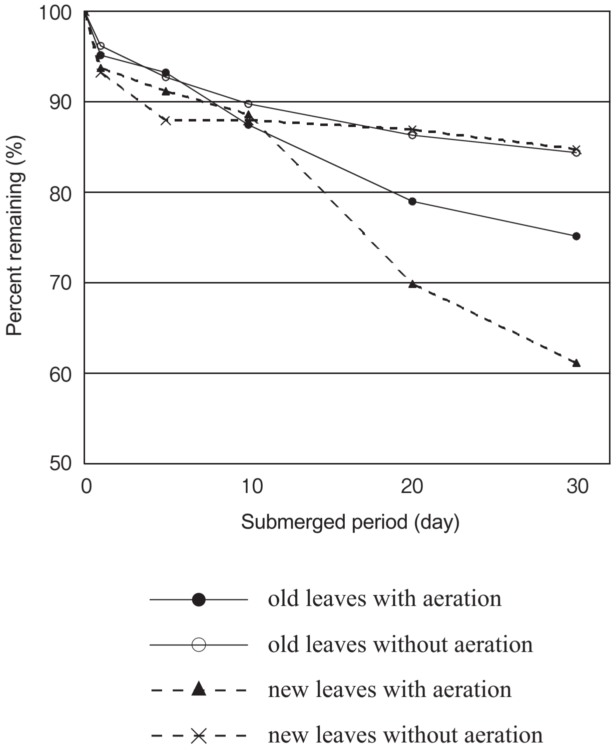

Fig. 2. Weight loss of each treatment at each sample occasion

short time that had elapsed since leafing. Leaves picked from the old branches of the tree were considered to be old leaves and were collected just prior to abscission, which had been growing since the previous spring and could be distinguished from new leaves by their dark-green color. These leaves were whole leaves and retained their original shape without any skeletonization. All leaves were collected on May 20, 2010. Stream water (100 L) was collected from the same stream for leaching experiments.

Collected leaves were washed with distilled water to remove aerosol dust and atmospheric gases[8], air-dried for 1 week and oven-dried at 80°C for 12 h. Old and new leaves were submerged in invertebrate-free stream water with or without air supply for a total of four treatments: old leaves with aeration; old leaves without aeration; new leaves with aeration and new leaves without aeration. In each treatment, 25 subsamples of five leaves were selected at random, weighed and immersed in 1, 000 cc of stream water in a beaker. All subsamples were allowed to stand at ambient temperature between 20-25°C.

Between June 10 and July 9, 2010, at 1, 5, 10, 20 and 30 days after submersion, five subsamples from each treatment were randomly selected. The leaves in each subsample were air-dried for 1 week, oven-dried at 80°C for 12 h and weighed.

The chemical characteristics of the water from each subsample were tested. The electric conductivity (EC) and hydrogen ion concentration (pH) of the water were measured using a water quality probe (WQC-20A, TOA Electronics Ltd., Japan). Cations (Li^+, Na^+, NH_4^+, K^+, Ca^{2+} and Mg^{2+}) and anions (F^-, Cl^-, NO^{2-}, Br^-, NO^{3-}, PO_4^{3-} and SO_4^{2-}) in the water were measured using ion chromatography (DX-120, NIPPON DIONEX K. K.,). The concentration of total carbon (TC; including total organic carbon (TOC) and inorganic carbon (IC)) and total nitrogen (TN) were measured with TOC-TN measuring instruments (TNC-6000, TORAY ENGINEERING K. K.,). Dissolved oxygen (DO) was measured with probe DR-700 (Hach Inc., USA).

3. RESULTS

3-1. Weight loss in leaves after submergence

Weight loss was calculated by subtracting the final weight of the leaves after submergence from the initial weight and was evaluated as percent remaining of the leaves (Fig.2). No fragmentation or invertebrate damage to leaves was observed in any samples. Before day 10, there was little difference between treatments; all leaves lost between 4-7 (%) of the starting weight. After day 10, old and new leaves in aerated water lost more weight than leaves without aeration and new leaves lost more than old leaves. Thus, the weight loss of leaves would almost complete for the first 10 days without aeration. The mean value of percent remainings at the end of experiment period in old leaves with reaeration, those without reaeration, newly leaves with reaeration, and those without reaeration are 75.3, 84.5, 61.2, and 84.8 (%), respectively, indicating considerable differences in each leaf between with-reaeration and without-reaeration treatments.

3-2. Changes in physiochemical parameters of water containing submerged leaves

3-2-1. Water temperature, pH, EC and DO

The ranges and means of measured parameters corresponding to the environmental conditions during the experiment period are shown in Table 1. In the Table, the effects of the differences in the weight of leaves submerged in the water on these parameters at each treatment are not considered. Initial values for temperature (17.5 °C), pH (7.5), EC (71.3 μS/ cm), and DO (11.3 mg/ l) were the same for all samples. Subsamples were kept in the laboratory without temperature control and were influenced by the ambient temperature; no marked differ-

Table 1. Overall comparison of ranges and means of measured values.

	Experimental condition		Water temperature(℃)		pH		EC (μS/cm)		DO (mg/l)	
	leaves	reaeratin	range	mean	range	mean	range	mean	range	mean
1	new	○	21.5−25.5	24.0	7.4−7.7	7.6	104.9−168.7	141.6	8.5−13.0	10.9
2	new	×	22.6−25.5	24.5	6.7−7.3	7.0	96.3−171.5	139.6	2.3− 5.3	3.8
3	old	○	21.3−25.3	23.9	7.2−7.7	7.5	85.4−129.6	107.3	8.8−13.5	11.7
4	old	×	22.4−25.6	24.3	6.9−7.6	7.2	77.4−111.6	98.6	4.0− 8.6	5.5

ences were observed in the mean temperature among the subsamples. There was little difference in the range and mean of pH in water containing old or new leaves with aeration. Mean pH increased from 0.3 to 0.6 in aerated samples. In samples without aeration, the range and mean of pH of water containing old leaves was slightly higher than water containing new leaves.

EC of water containing leaves increased with time and the maximum observed values was the last measurement in all cases. This indicates that chemicals leached progressively from leaves and total leachate depended on time submerged irrespective of aeration. Maximum EC (μS/ cm) after 30 days for each treatment were: new leaves with aeration, 141.6; new leaves without aeration, 139. 6; old leaves with aeration, 107. 3; and old leaves without aeration, 98.6. The mean EC values during the measurement period were higher in new leaves without aeration and increased slightly when aerated.

DO concentration of the water in the beakers with aeration (Table 1) was similar to that in pools of the Takeo River in June (mg/ l)[15].

3-2-2. Total Carbon and Total Nitrogen

Figure 3 shows the mean TC (a) and TN (b) concentration of the water corresponding to the experimental conditions after submersion of each group of leaves for 30 days. The concentrations are given per 1 g of leaves in the figure. In the present measurements, TC concentration was equal to TOC concentration, because no IC was detected in any sample.

In all samples, the TC in each treatment increased to 50 mg/ l in the first 5 days (Fig.3), as organic carbon was leached from the leaves. After 5 days, TC concentrations remained constant in non-aerated water for both new and old leaves and TC concentrations in aerated water increased after day 10. There were considerable differences in TC (mg/ l) between treatments at the end of the experiment (old leaves with aeration, 71.2; old leaves without aeration, 51. 6; new leaves with aeration, 75. 2; new leaves without aeration, 56. 6), indicating differences between leaching in aerated or non-aerated conditions.

As with TC concentrations, TN concentration increased for the first 5 to 10 days. Thereafter, non-aerated treatments were nearly constant, whereas TN concentration continued to rise after the 10th day in aerated treatments (Fig.3). Leaching rates of TN from leaves immersed in water increased with aeration after day 10. The mean concentration of TN (mg/ l) of each treatment at the end of experiment was: old leaves with aeration, 5. 1; old leaves without aeration, 2.2; new leaves with aeration,

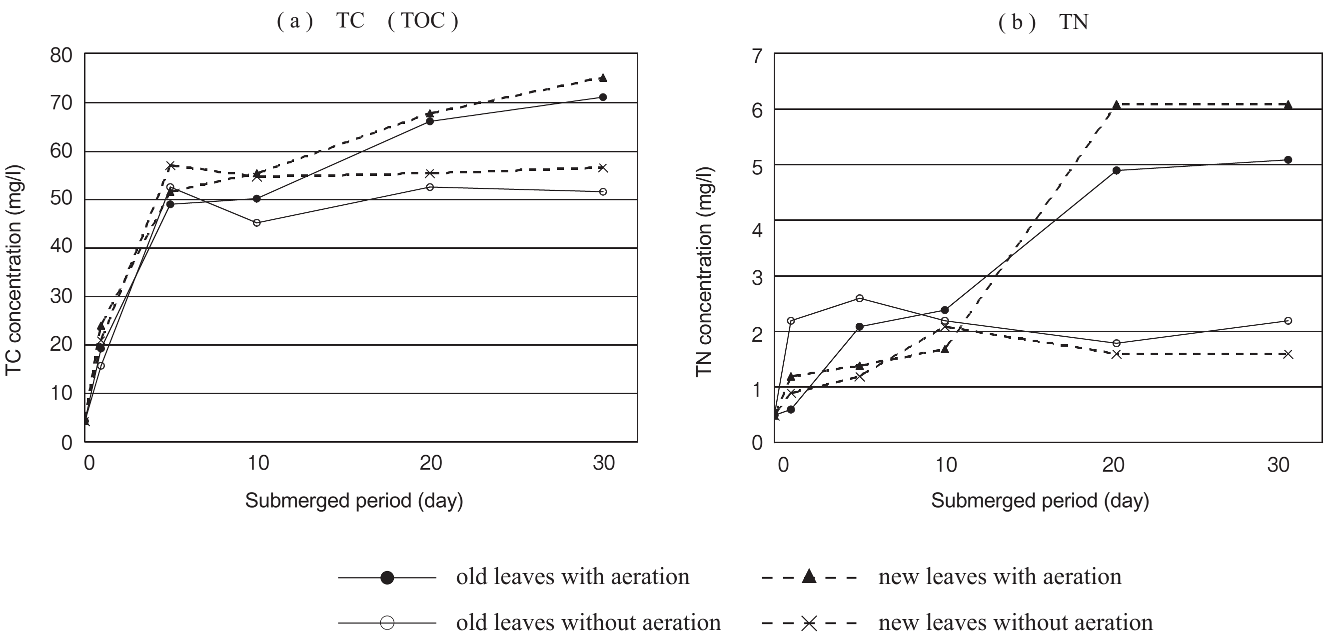

Fig. 3. TC and TN concentrations for sample water in each treatment at each sample occasion.

Table 2. Final concentration of ions in distilled water, after 30 days, for each treatment, expressed per g leaf starting weight

leaves	reaeration	cations					anions			
		Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	NO^{3-}	PO_4^{3-}	SO_4^{2-}
old	○	0.37±0.04	2.94±0.24	7.31±0.02	4.68±0.09	8.76±.006	4.51±0.14	1.43±0.03	−	4.45±0.14
old	×	2.27±0.05	2.24±0.15	8.32±0.12	4.89±0.13	8.22±0.29	5.88±0.20	0.71±0.13	−	4.59±0.02
new	○	1.96±0.12	3.08±0.04	23.50±0.32	4.53±0.17	4.85±0.31	5.56±0.03	0.31±0.00	4.52±0.30	4.73±0.02
new	×	1.57±0.04	1.52±0.10	26.91±0.08	5.09±0.02	4.19±0.09	4.81±0.04	0.18±0.02	5.96±0.09	5.13±0.06

mean±standard error

6.1; and new leaves without aeration, 1.6.

3-2-3. Ion concentrations

Table 2 shows the ranges and means of concentrations of cations and anions leached from leaves submerged in water after 30 days from submergence. In table 2, the concentrations per 1 g leaves are indicated. Li^+, F^-, Cl^-, NO^{2-} and Br^- ions were not detected. Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+} cations and Cl^-, $NO^{3-}$and SO_4^{2-} anions were detected in old and new leaf treatments. PO_4^{3-} was not detected in old leaf treatments.

The most abundant cations in old leaf treatments were K^+ and Ca^{2+} and the most abundant in new leaf treatments were K^+ and Mg^{2+} (Table 2). After 30 days, K^+ concentration in new leaf treatments was one order of magnitude higher than the concentration of other ions: 70% of total ion concentration in aerated treatments and 30% in without-aeration treatments. The abundant anions were Cl^- in old leaf treatments and Cl^-, NO^{3-} and PO_4^{3-} in new leaf treatments.

The Ca^{2+} and NO^{3-} concentrations of treatment water on day 30 were higher in old leaf treatments than in new leaf treatments; conversely, the K^+ and PO_4^{3-} concentrations were higher in new leaf treatments than in old leaf treatments. The concentrations of NH_4^+, Ca^{2+} and NO^{3-} were higher with aeration than without aeration for both leaf types, indicating that the leaching rates of these ions was increased by oxygen.

4. DISCUSSION

4-1. Overall relationships between mean initial dry-weights of leaves and leaching rates of leachates from leaves

The relationship between the mean initial dry-weights of leaves and the overall leaching rates of TC and TN corresponding to the experimental conditions are shown as Fig.4. In the figuer, the overall leaching rates of TN and TC were calculated by dividing the concentrations of TC and TN by the days after submergence in each treatment.

The mean initial dry-weights of leaves are under 1.0 g in all the old leaves and are over 1.0 g in most of the new leaves. No clear correlations between the overall leaching rates of TC and TN and the mean initial dry-weights of leaves in new leaves, however, the overal leaching rates of TC and TN tend to increase with increasing the mean initial dry-weight of leaves in old leaves.

The relationship between the mean initial dry-weights of leaves and the overall leaching rates of anions and cations are shown as Fig. 5. In the figuer, the overall leaching rates of the ions were calculated by dividing the concentrations of the ions by the days after submergenc in each treatment. The overall leaching rates of anions and cations increase within the range from 0.85 g to 1.10 g of the mean initial dry-weight of leaves and the leaching rates of cations and anions in this range are $K^+ > Mg^{2+} > Na^+ > Ca^{2+} > NH_4^+$ and $> SO_4^{2-} > Cl^- > PO_4^{3-} > NO^{3-}$, respectively. No clear correlations are observed between the overall leaching rates and the mean initial dry-weights of leaves.

Detailed explanation of the leaching characteristics of these leachates will be descrived later.

4-2. Weight loss from evergreen and deciduous leaves

When leaves fall into streams, soluble organic and inorganic chemicals begin to leach immediately. The second stage of leaf decomposition is microbial colonization and growth, which in turn promote leaf fragmentation by invertebrate activity. The initial leaching from leaves is part of leaf decomposition.

In deciduous leaves, most leaching occurs within a few days of submergence. For example, autumn-shade leaves in water can lose up to 40% of their dry weight in a few days[10]; the ash-free dry weight of sugar maple, yellow birch, and beech was 85.4%[21] of the initial weight after 2 days submerged in the laboratory. Webster *et al.* (1986)[26] indicated that up to 25% of the initial dry weight of some riparian deciduous tree leaves (e.g., *Alnus* sp., *Salix* sp.) was lost by leaching in the first 24 h of submergence.

In contrast to these results from deciduous species, evergreen leaves of *Q. glauca* in the present study lost 4~7% after 1 day and leaves submerged without air lost less than 25% of the initial weight after 30 days (refer to Fig.2). This result is similar to tests on *Q. alba* in which 5. 16% of the initial weight was lost within 24 h[22]. Overall weight loss from evergreen leaves is less than a quarter of that from deciduous leaves. This may be due to differences in the outer surfaces of the leaves.

4-3. Relation between weight loss and TC leached from the leaves

There was a significant correlation (r^2) between TC and weight loss (Fig.6(a)) for each treatment: old leaves with aeration, 0.79 ($P < 0.01$); old leaves without aeration, 0. 60 ($P<0.01$); new leaves with aeration, 0.66 ($P<0.01$), and new leaves without aeration, 0.40 ($P<0.001$). The correlations were higher for aerated treatments.

The leaves in aerated water lost 4-7% of the initial weight in the first day after submergence and weight loss slowed in treatments without aeration (refer to Fig. 2). The amount of TC leached from leaves may vary with

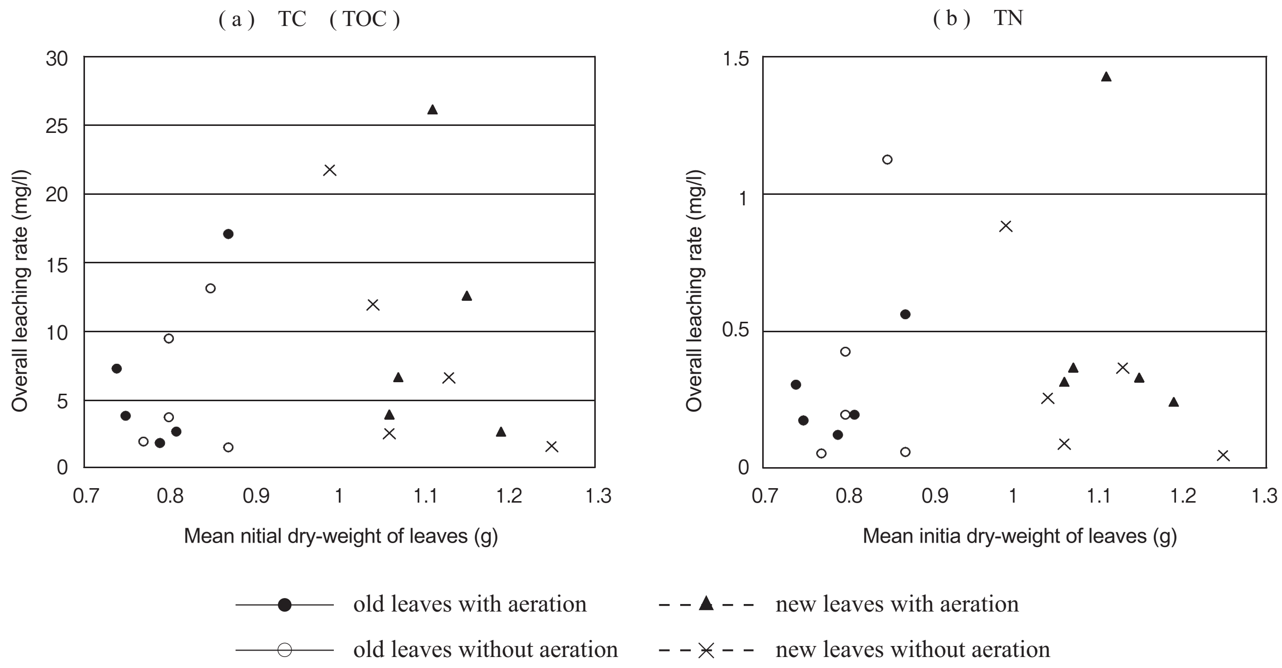

Fig. 4. Correlation between mean initial dry-weight of leaves and overall leaching rates of TC (a) and TN (b) corresponding to experimental conditions

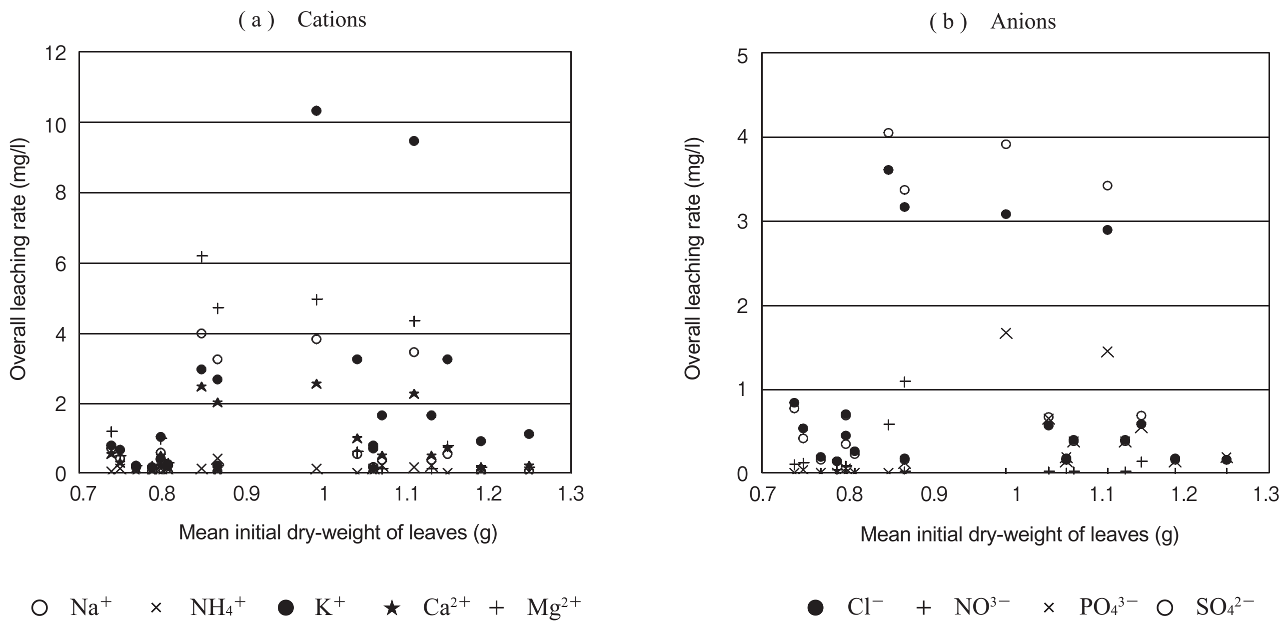

Fig. 5. Correlation between mean initial dry-weight of leaves and overall leaching rates of cations (a) and anions (b) leached from leaves.

tree species, temperature, humidity and microbial activity[7]. Carbon loss from leaves of *Salix* was less than 8% of initial content in the first 24 h of immersion[23]. Leaves from other deciduous species, therefore, lose most soluble components in the first 24 h of immersion. In the present study, however, leaching of TC from evergreen leaves was slower and continued for the first 5 days before reaching a maximum.

The differences in weight loss pattern and TC concentration between deciduous and evergreen leaves arise from differences in leaf composition and structure. TC is derived from soluble carbohydrates, organic acids, hemicellulose and other organic material. Soluble carbohydrates are lost through the cuticle on the surface

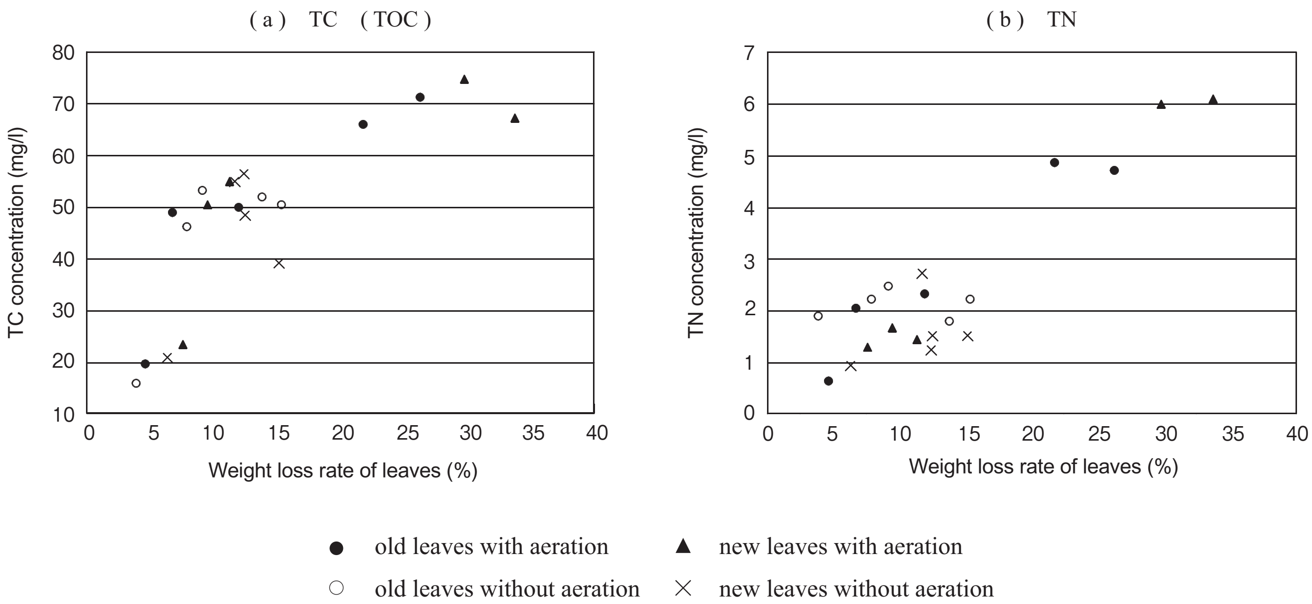

Fig. 6. Mean percentage weight loss, TC (a) and TN (b) for each treatment.

Table 3. Changes in C/ N ratios of water with elapsed time

experimental condisions		stream	submerged period (days)				
leaves	reaeration		1	5	10	20	30
old	○	9	31.2	22.9	21.1	13.5	14.0
old	×	9	7.2	20.3	20.5	28.8	23.1
new	○	9	19.5	36.8	32.9	11.2	12.3
new	×	9	22.4	45.9	25.6	34.5	35.8

of evergreen leaves, and the thick cuticle of evergreen leaves reduces the rate of decomposition. The rate of decomposition of leaf litter in the water may be increased by abrasion of leaf surfaces. For examples, one major constituent of the leaf cuticle is lipid, which is lost more rapidly than total mass[1)]. Broadleaf evergreens such as *Q. glauca*, however, break down slowly.

The tough outer surfaces of evergreen leaves (e. g., cuticle) may delay leaching and subsequent weight loss in leaves until the outer layer of the epidermis, which consists of cutin, breaks down in water. Since TC leaching from evergreen leaves was almost complete 5~10 days after submergence, weight loss after 10 days may comprise leachates other than carbon.

4-4. Leaching of TN from leaves with decomposition

The correlation coefficients for aerated treatments were significant ($P < 0.001$), but not for treatments without aeration: old leaves with aeration, 0. 92; old leaves without aeration, 0.00; new leaves with aeration, 0.98; and new leaves without aeration, 0.12. As with TC concentrations, TN concentration increased for the first 5 to 10 days. Thereafter, TN concentration in non-aerated treatments were nearly constant TN continued to rise after the 10th day in aerated treatments (Fig. 6b).

As decomposition proceeds, nitrogen concentration in the leaves increases[27)] presumably as total carbon falls and higher leaf decomposition rates may occur in nutrient-rich conditions[10)] due to the greater availability of nitrogen. There was a direct relationship between nitrogen and leaf weight loss in the present experiments. The observed increases in TN in the treatment waters were due in part to leaching of N from leaves during decomposition, which was accelerated by aeration.

Leaf decomposition rate depends on the C/ N ratio of the leaf, and as a general rule, a C/ N ratio of approximately 10: 1 is considered optimal for decomposition of organic matter. Plant materials with low C/ N ratios decompose more quickly than those with a higher C/ N ratio[18)]. The C/ N ratios of treatment water changed over time (refer to Table 3). In the present study, the C/ N ratios of treatment water were measured, rather than the C/ N ratios of leaves as in previous studies. After day 20, C/ N ratios were lower in aerated treatment water and close to the optimal level for leaf decomposition of 12~14. Aeration increased the rate of TN leaching from leaves.

By the way, leaf breakdown in natural streams is faster in riffles than in than in pools[26)]. The DO saturation level in riffles is usually higher than in other stream habitats such as pools and side-pools, as oxygen diffusion across the gas-liquid interface is accelerated by disturbance of

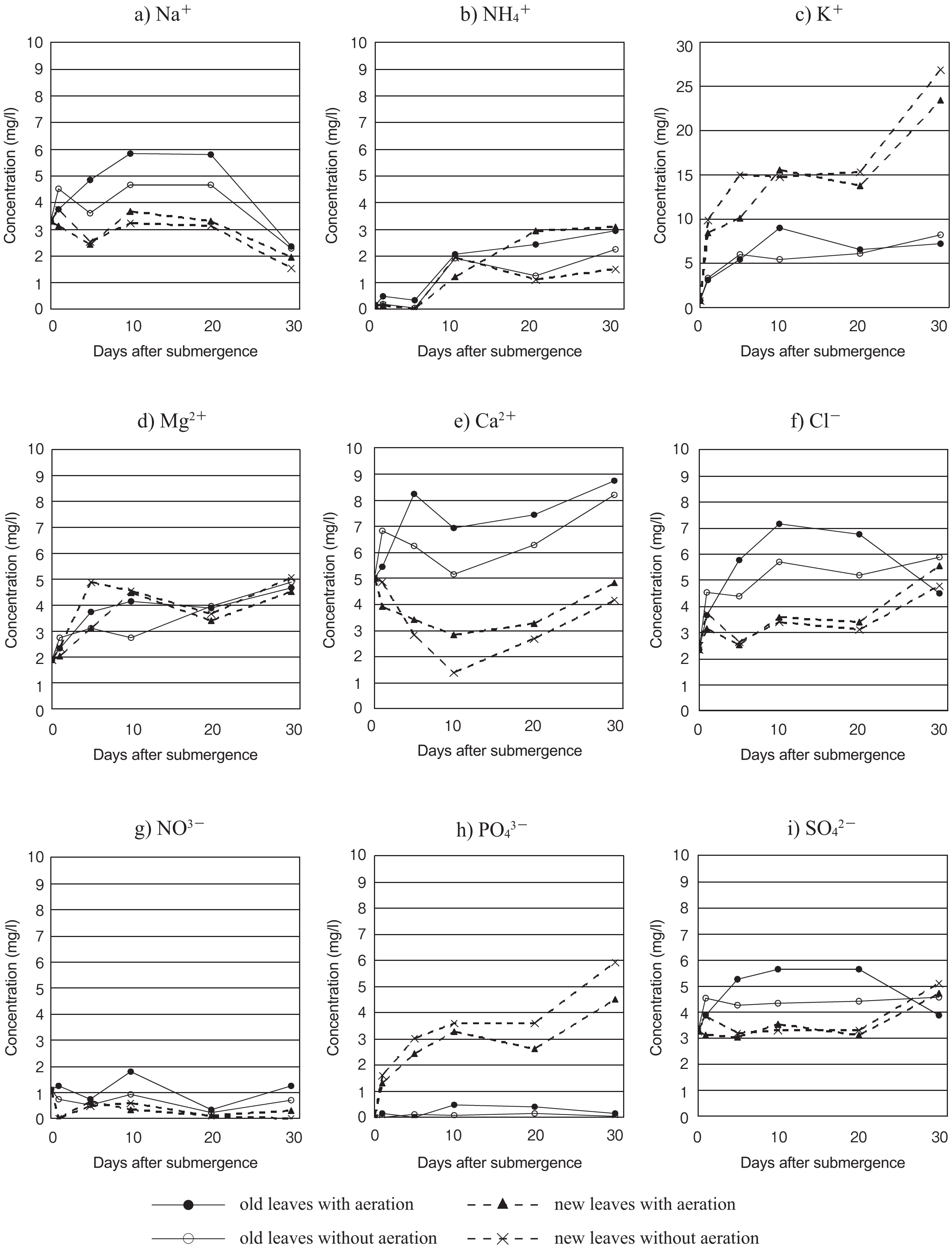

Fig. 7. Mean ionic concentrations in sample water for each treatment at each sample occasion.

the water surface as well as water temperature[15]. The present results indicate that aeration accelerates the weight loss of the leaves in treatment water by leaching, and suggest that relatively high DO concentrations, as well as longer retention periods attributed to the substrate type and more macroinvertebrates[24], would promote the decomposition of leaves in riffles in natural streams.

4-5. Ion concentration

The pattern of leaching from leaves over time for each ion was inferred from Fig. 7. Variation from initial ion concentrations in treatment water were attributed to ions leached from leaves, decomposition of the leachates[26] and production and consumption by microorganisms present in treatment water. No significant correlation was observed between the ion concentrations, leaves weight loss or TC and TN in treatment water.

The most dominant cation was K^+, accounting for around 70% of all cations in aerated sample waters (refer to Table 2). By day 30, NH_4^+, K^+, Mg^{2+} and Cl^- concentration were more than two times higher than the initial concentrations in all treatments. This observation suggests that these ions leached into treatment water during leaf breakdown. The increase in NH_4^+ concentrations during the experimental period was predicted by the results from a previous study[25] that indicated that nitrogen concentration in the leaves increases as decomposition proceeds.

Leaching of K^+ was higher in new leaves, irrespective of aeration. K^+ ions are concentrated in young leaves and buds in plants[18] and rapid decreases of K^+ in tree leaves and subsequent release of K^+ from the leaves by leaching occurs [3, 12] during decomposition. In consequence, new leaves release more K^+ during decomposition in the experiments.

However, in contrast to the high K^+ ratios in the water of the laboratory leaching experiments, the initial K^+ concentrations in the stream water were lower than other cations and anions. The lower concentration of K^+ in the stream water would suggest that there is a differential utilization of K^+ by the biota and that stream sediment acts as an important agent for the removal of leachates from water[17]. Clay in the sediment may bind and retain K^+. Potassium may also be retained by stream biota if there is a net increase in biomass. Biological consumption may occur in PO_4^{3-}, which was not detected in the stream water during the measurements.

The Ca^{2+} concentrations at day 30 in old leaf treatments were nearly twice those in new leaf treatments. As the amount of Ca^{2+} in leaves increases throughout the growing season and Ca^{2+} is retained until breakdown of the leaves occurs[18], it is possible that older leaves release more Ca^{2+} than new leaves. Previous studies[4, 18] attributed rapid K^+, Mg^{2+} and Ca^{2+} losses to leaching and the order from most rapid to the slowest was $K^+ > Mg^{2+} > Ca^{2+}$; in other words, Ca^{2+} was less susceptible to leaching than K^+ or Mg^{2+}. The results from the present study are similar to those of the previous studies; however, the leaching rates of Ca^{2+} in old leaves were equivalent to leaching rates of Mg^{2+}. Slower leaching of Ca^{2+} in previous studies, therefore, may be attributed to the use of new leaves.

Phosphate (PO_4^{3-}) concentrations in new leaf treatments nearly doubled, while those in old leaf treatments were nearly constant. Since microbes use leaf substrate as an energy source and assimilate phosphorus from the water[12], leaves might gain phosphorus during submergence.

The present study observed increases of PO_4^{3-} concentration in new leaf treatments. As decomposition of the leaves proceeds, phosphorus and nitrogen concentrations in the leaves increase following initial leaching[25]. This also implies that new leaves decompose more rapidly, possibly because the outer cuticle is thinner, allowing PO_4^{3-} leaching. *Q. glauca* leaves of different ages may have different chemical composition, and this may also influence the leaching rate of PO_4^{3-} from the leaves.

Sulfate (SO_4^{2-}) ion concentration in treatment water increased slightly over initial concentrations by day 30. Large amounts of sulfate appear to accumulate in the watershed and biomass utilizes sulfur[21]. Some is returned to the water as SO_4^{2-} by leaf decay, although atmospheric gases and dust on leaf surfaces may also contribute to sulfate ions.

Na^+ is generally found in association with Cl, indicating their common origin. Most Na^+ found in river water is derived from rock weathering, but some Na^+ and Cl^- may be supplied through rainwater. Closer to the coast, rainwater may contribute significantly to ion supply[1].

5. CONCLUSION

In the present study, physicochemical parameters such as EC and pH, concentrations of specific ions such as K^+ and Mg^{2+}, and TC and TN concentrations continued to increase in all treatment water samples for 30 days following the immersion of evergreen tree leaves in stream water. This is attributed to the leaching of some components from the leaves. The nutrient content of litter fall is extremely variable and depends on the natural variation of nutrient concentration in plant tissue and the timing of litter fall. The leaching rates from leaves in this study may have been affected by these factors.

Mineral ions in stream water originate from various sources. For example, it is said that Mg^{2+} and Ca^{2+} in streams originate almost entirely from the weathering of sedimentary carbonate rocks, and approximately 90% of K^+ originates from the weathering of silicate materials, especially potassium feldspar and mica[1]. Based on the results of the leaching experiment in the present study, however, biomass contribution to stream water composition, i.e. through leachate from leaf litter, is also important.

Because the leaching tests in the present study were conducted with the stream water, the treatment water in the present study was not sterile and contained several kinds of microorganisms. The process by which leaves lose constituents to leaching and microbial colonization proceeds within streams is called conditioning[1]; conditioning may alter carbon quality for detritus feeding invertebrates[26]. Invertebrates play a major role in leaf breakdown after conditioning. Thus, the decomposition of the tough surface of evergreen leaves consisting of cutin might be accelerated during the conditioning period, being promoted leaching carbon.

Decomposing leaves provide minerals, nutrients and organic carbon to stream ecosystems. Future studies should verify the leaching rates indicated by the present study through further statistically significant measures and dissolved organic carbon leached from evergreen leaves. In addition, it is necessary to clear the chemical contents of soils in which plants have been growing, because materials absorbed from their roots tend to be accumulated in the plants, leaching when submerged.

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南九州河畔域に生育するアラカシ（*Quercus glauca*）リーフリターの溶出特性について

北村泰一
南九州大学環境園芸学部環境園芸学科
緑地保全学研究室

要　約

河畔域から渓流に供給されるリーフリターは膨大な量にのぼると推測され，その溶出成分は渓流水質の形成に重要な役割を果たすものと思われるが，落葉広葉樹リーフリターの分解に伴う重量損失とリター構成成分の変化については知られているが，常緑樹リーフリターの溶出特性については不明な点が多い。そこで本研究は，南九州河畔域に広く分布する常緑広葉樹のアラカシリーフリターの溶出特性を明らかにすることを目的とした。

2010年5月，一ツ瀬川支流竹尾川下流（宮崎県西都市）の河畔域に生育するアラカシの新葉（2010年春以降に形成された葉）を採取し，十分な洗浄・乾燥と重量測定の後，1,000（CC）の現地渓流を満たした50個のビーカーに5枚ずつ投入してサブサンプルとし，温度調整をしない実験室に置いた。このうち25個のビーカーには市販ポンプにより酸素を供給し続けた。同時に，アラカシ古葉（2009年以前に形成された葉）に対しても，同様な処理を行った。葉を投入してから1，5，10，20，30日後に，各実験区から無作為にサブサンプルを5個づつ回収し，葉の乾燥重量を計測し，投入水に含まれる全炭素量（TC），全窒素量（TN），陽イオン濃度，陰イオン濃度を測定した。

投入から1日後の重量損失は4~7％で，これは広葉樹リーフリターの約1/4であり，10日後の重量損失も10％程度であり広葉樹に比較して緩慢であった。10日以降の重量損失は，酸素を供給することにより促進された。重量損失に比例してTC，TNの溶出は進んだが，10日以降は酸素の供給がない場合は，TC，TNの溶出はほぼ停止した。これらの結果から，常緑樹リーフリターでは表面を覆うクチン質が葉の重量損失を遅らせ，酸素を供給することによりクチン質の分解は促進される

と類推した。

陽イオン，陰イオンは，重量損失の進行・酸素供給の有無とは無関係に溶出し，30日後ではK^+が全陽イオンの70％を占めた。また，NH_4^+，K^+，Mg^{2+}，Cl^-濃度が倍増し，Ca^{2+}は古葉で，PO_4^{3-}は新葉で溶出が進んだ。以上の結果から，河畔域から渓流に供給される常緑樹リーフリターの溶出段階において放出されるイオン成分は，渓流水中のイオン組成を規定する重要な因子となりうることが示唆された。