Journal of Environmental Science International
25(10); 1369~1379; October 2016

pISSN: 1225-4517 eISSN: 2287-3503
http://dx.doi.org/10.5322/JESI.2016.25.10.1369

ORIGINAL ARTICLE

A Study on Anion Generation according to Vertical Structures of Tree

Jeong-Ho Kim, Deuk-Kyun Oh[1)], Yoo-Hwan Seo[2)], Jae-Hyeon Park[1)], Yong-Han Yoon[*]

Department of Green Technology Convergency, Konkuk University, Chungju 27478, Korea
[1)]*Department of Forest Science, Konkuk University, Chungju 27478, Korea*
[2)]*Graduate school of Horticulture, Chiba University, Chiba 271-8510, Japan*

Abstract

This research assessed the disparity in anion generation according to the vertical structure of a *Zelkova Serrata* tree for the purpose of creating a pleasant and green city environment. Measurements for the study were conducted between July and August of 2014 in Chung-ju in the central region of the Republic of Korea. The average anion generation of vertical structure trees during active photosynthesis periods was: L Section (839.0 ea/cm^3) > M Section (664.6 ea/cm^3) > U Section (472.0 ea/cm^3). According to DMRT analysis, significant difference was found in the average between the L, or M Locations and the U Locations. During dormant photosynthesis periods, records showed that the anion production at the M Location (1,212.5 ea/cm^3) > L Location (1,050.4 ea/cm^3) > H Location (844.1 ea/cm^3), According to DMRT analysis, the difference within each location was significant for α=0.05. In a comprehensive analysis of the weather factors in each vertical structure, anion generation during active photosynthesis periods showed a positive correlation with solar radiation and a negative correlation with wind speed. Dormant photosynthesis periods showed negative correlations with both solar radiation and temperature, and positive correlations with relative humidity and wind speed. Predictions from a multicenter retrospective study showed that during active photosynthesis periods, $Y_1 = 282.443X_1 + 512.07$, and $Y_2 = 314.337X_1 + 16.913X_2$, while during dormant photosynthesis periods, $Y_1=391.009X_1 + 840.043$, and $Y_2=351.412X_1 + 32.765X_2$.

Key words : Altitude of the sun, Weather, *Zelkova Serrata*, Correlation analysis

1. Introduction

The value of Green space in the 21st century has expanded from mere productive and materialistic values to encompass environmental values that are of growing interest. The environmental value of green spaces have gone beyond air purification and sound-buffering and has risen to a new height due to new evidence proving reduction of microclimates in cities, energy preservation, health benefits and more pleasant effects. The sound, oxygen, scenery and anions produced by the green spaces within cities are of critical important to increasing the comfort of cities. Of these, anions, which has been proven to stimulate the parasympathetic nerve of humans effectively calming the blood pressure, heart rate and breathing (Buckalew and Rizzuto, 1982; Krueger 1985; Rho and Kim, 2007; Kim et al., 2008), has

Received 4 August, 2016; **Revised** 1 September, 2016;
Accepted 2 September, 2016
[*]**Corresponding author** : Yong-Han Yoon, Department of Green Technology Convergency, College of Science Technology, Konkuk University, Chungju 27478, Korea
Phone: +82-43-840-3538
E-mail: yonghan7204@kku.ac.kr

become an important source of measuring a city's comfort level. An anion is a negatively charged ion within the molecules and atoms in the air. These anions are mass released through the plants in the green spaces and are created through photosynthesis that follow a two-step process. First, due to the photosynthesis of plants, CO_2 in the air is absorbed, then by using H_2O as a fuel, is synthesized with carbohydrates. During this process, O_2 is released into the atmosphere and this O_2 adheres with the ions from the ground and forest to produce anions. Second, dry weather incurs evaporation from soil that is full of water from rainfalls. The evaporated water molecules are hit by far-infrared radiation from the sun, which dismantles the water molecule into an anion OH- $(H_2O)n$ and a cation $H_3O+(H_2O)n$. In the aftermath, the heavier cations fall to the ground transitioning the air into an anion environment (Skalny et al., 2004; Luts and Salm, 1994; Perkins and Eisele, 1984).

Researches show that the effect of anions having a legitimate effect on humans is when the level of anions in the air is at 400-1,000 ea/cm^3 comparatively, green spaces in cities are known to produce around 700 ea/cm^3 of anion (Yatakai, 1993; Karjalainen et al., 2010; Jo 2009). Following such reports, there has been much research on the anion generation in green spaces, weather, cities, forests and rivers and from these research the relationship between forests and anions were used to prove the high statistical significance of soil moisture and anions. Further research has shown that the producers of anions are ranked as thus: broad-leaved mixed stand forests, oak forests, pine forests, oak-pine mixed forests (Um and Kim, 2010). It was also found that areas was damp earth had the highest anion generation of 3254.44 ea/cm^3 (Nam, 2013) and that the ideal environment for the highest anion generation was temperature between 31 and 35 and humidity between 62 and 64% (Kim et al., 2012). Also, research showed that forest biotopes and farmland biotopes, which had high levels of green space had higher anion generation (Kim et al., 2012).

Extending from such papers, this research aims to measure a single tree's unique characteristics and value instead of a massive forest to measure the specific weather factors in relation to anion generation in hopes of creating a foundation for better city green space.

2. Materials and Method

2.1. Selection of tree

This study chose the *Zelkova Serrata* for the research as it is one of the South Korea's five most popular landscape trees; it has long life expectancy; its crown width is wide; it possesses high usability in both gardens and roadsides; and it has deep shades in the summer and reddening in the autumn resulting in high ornamental value. Furthermore the *Zelkova Serrata*'s upper areas have long branches that include hardened and drought resistant leaves that produce scenic glistening. While it's lower areas have parts that is sensitive to humidity stress (Kim, 2003), such separate ecology system creates disparate biological reactions between the lower and higher areas. Therefore this disparate biological relationship creates an ideal environment for assessing the anion generation resulting from vertical structures in trees.

The specific *Zelkova Serrata* tree used for assessment was oval shaped of height 5.64 m, long width 8.21 m, short width 7.55 m, clear length 2.17 m, source diameter 38 cm, the average leaf number being 421.37 ea/cm^3. The reason for choosing the grass areas (Table 1) was as minimalize the effects of the ground has on trees and micro meteorological phenomena.

To assess the anion generation resulting from the vertical structure of trees, the areas of the *Zelkova Serrata* trees were divided in to the U (Upper)

Table 1. Status of *Zelkova Serrata*

	Height (m)	Width of crown (m)	Clear length (m)	Diameter (cm)	Leaf Number (ea/cm^3)
Values	5.64	8.21 x 7.55	2.17	38	421.37

Location, M (Middle) Location and the L (Lower) Location. For the U Location and the M Location, the crown height was split in two and was measured 4.0 m and 3.5 meters off the ground respectively. For the L Part, measurement was placed on the 1.2 m breast height; the contemporary height of measuring anion generation (Fig. 1).

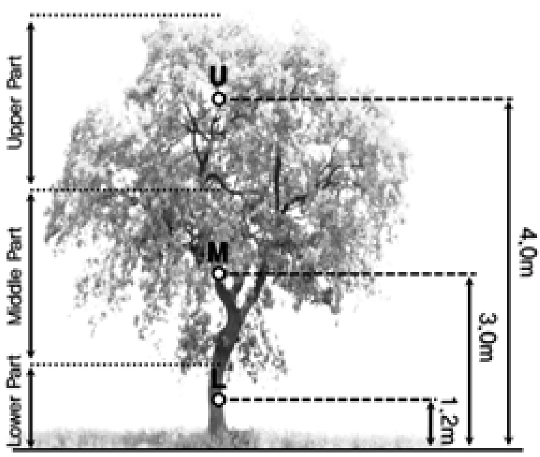

Fig. 1. Measurement points schematic diagram according to vertical structure.

2.2. Method of measurement and analysis

Measurements were conducting between July and August of 2014, and the measurements were taken days within this time period that had clear weather and minimal cloud cover. To assess the anion generation made by the tree' physiological function, measurements were taken during both active photosynthesis periods between 10:00 and 12:00 and dormant photosynthesis periods between 13:00 and 15:00. Also, weather factors and anion generation measurements were taken 10 minutes at each part; to increase accuracy of measurement data, research was equipped with data log function in the measurement device and laptops. In assessing the weather factors, solar radiation used LP02 (Hueselux Inc, USA) while other weather factors as temperature, relative humidity and wind speed was measured by TSI-9535 (NICO Inc, Japan). Anion generation measurement device was COM-3600pro (NICO Inc, Japan).

Analysis was through the statistic program, SPSS Statistics Ver.21.0 and Pearson's two-parameter correlation coefficient, which was used calculate the correlation between the weather factors and the anion generation. To assess the disparity of anion generation from each part, one-way layout variance analysis and multiple regression analysis was utilized.

3. Result

3.1. Weather factors and anion generation during active photosynthesis periods

The results of the weather factors for each of the measurement parts were as thus. For solar radiation, U Location (83.0 W/㎡) > L Location (74.1 W/㎡) > M Location (47.8 W/㎡). For temperature, the results were similar to radiation as U Location (29.8℃) > L Location (29.2℃) > M Location(28.7℃) For relative humidity, M Location (71.4%) > U Location (71.3%) > L Location (64.0%). For wind speed, M Location (0.77 m/s) > L Location (0.65 m/s) > U Location (0.14 m/s). Furthermore, according to DMRT analysis, solar radiation had average significant difference for U,L part and M part. Using the same analysis, temperature and relative humidity had no significant different due to vertical structure. As for wind velocity, the average significant difference

Table 2. Measurement points of average weather by photosynthetic activity

	Solar radiation (W/㎡)	Temperature (℃)	Relative humidity (%)	Wind speed (m/s)
U	83.0 ± 1.0^{az}	29.8 ± 0.5^{a}	71.3 ± 1.6^{a}	0.14 ± 0.02^{b}
M	47.8 ± 5.8^{b}	28.7 ± 0.5^{a}	71.4 ± 1.4^{a}	0.77 ± 0.04^{a}
L	74.1 ± 1.6^{a}	29.2 ± 0.4^{a}	71.6 ± 1.0^{a}	0.65 ± 0.07^{a}

between U, L part and M part was around 5% (Table 2).

The average anion generation was L Location (839.0 ea/cm^3) > M Location (664.6 ea/cm^3) > U Location (472.0 ea/cm^3). Location L's momentary maximum anion generation of was 953.5 ea/cm^3 and the momentary minimum anion generation was 691.0 ea/cm^3. Location M's momentary maximum anion generation of was 823.9 ea/cm^3 and the momentary minimum anion generation was. Location L's momentary maximum anion generation of was 657.3 ea/cm^3 and the momentary minimum anion generation was 291.2 ea/cm^3. The standard errors of the three locations were 14.3 for L part, 17.7 for M part, 24.5 for U part. DMRT analysis indicated that the average significant difference of the parts were at L, M parts and U part (Fig. 2).

By using Pearson's two-parameter correlation coefficient to see the correlation between weather factors and anion generation, U part saw positive correlation with temperature and negative correlation with relative humidity. M part saw positive correlation with wind velocity and relative humidity while seeing negative correlation with solar radiation. For the L part, which produced the most anion generation, saw positive correlation with solar radiation and wind velocity (Table 3).

3.2. Weather factors and anion generation during dormant photosynthesis periods

During dormant photosynthesis periods (13:00 ~15:00), solar radiation for each part was 138.7 W/㎡ for L Location, 86.3 W/㎡ for M Location, 28.6 W/㎡ for L Location. For temperature, the hierarchy was similar with solar radiation as U Location was the highest with 33.6℃, M Location had 32.1℃, and L Location had 31.4℃. For relative humidity, L part which saw the lowest temperatures was the highest by 61.0%, while M Location and 60.4% and U Location and 59.3%. Wind speed on the other hand, was strongest in the M Location with 0.73 m/s with U

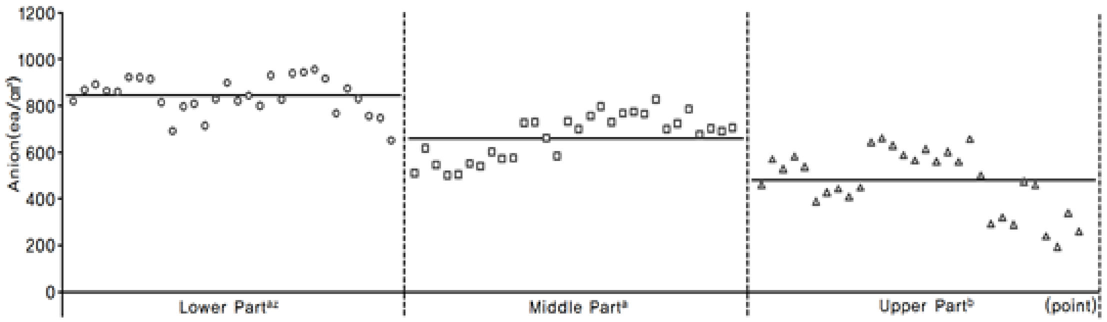

Fig. 2. Measurement points of anion generation at photosynthetic activity z. Different letters in the same column indicate a significant difference at $P < 0.05$ according to Duncan's multiple range test.

Table 3. Corrletaion between weather and anion by photosynthetic activity

			Anion	Solar radiation	Temperature	Relative humidity
U	Solar radiation	C.C[z]	-.106			
		P value	.578			
	Temperature	C.C	.802**[y]	-.074		
		P value	.000	.698		
	Relative humidity	C.C	-.668**	.068	-.954**	
		P value	.000	.723	.000	
	Wind speed	C.C	-.334	.169	-.267	.138
		P value	.071	.372	.154	.469
M	Solar radiation	C.C	-.408*[x]			
		P value	.025			
	Temperature	C.C	-.287	.804**		
		P value	.124	.000		
	Relative humidity	C.C	.405*	-.834**	-.985**	
		P value	.026	.000	.000	
	Wind speed	C.C	.603**	-.210	-.152	.229
		P value	.000	.266	.423	.223
L	Solar radiation	C.C	.378*			
		P value	.040			
	Temperature	C.C	-.097	.008		
		P value	.611	.968		
	Relative humidity	C.C	.068	-.246	-.883**	
		P value	.723	.191	.000	
	Wind speed	C.C	.377*	.251	-.353	.074
		P value	.040	.181	.055	.698

[z]. C.C = Coefficient of correlation
[y]. ** = The correlation of coefficient is significant at the 0.01 level
[x]. * = The correlation of coefficient is significant at the 0.05 level

Location, which had the high solar radiation and temperature with 0.13 m/s, and L Location having 0.64 m/s. According to DMRT analysis solar radiation and temperature saw average significant difference for each U part, M part and L part. Relative humidity saw average significant difference in U part and L part, while wind velocity saw a significant difference of around 5% between the M, L part and U part (Table 4).

Anion generation showed that M Location (1212.5 ea/cm^3) > L Location (1050.4 ea/cm^3) > H Location (844.1 ea/cm^3). For M Location, the momentary maximum anion momentary minimum anion generation was 1112.80 ea/cm^3. For L Location, the momentary maximum anion generation was 1184.7 ea/cm^3 and the momentary minimum anion generation was 858.3 ea/cm^3. For H Location, the momentary maximum anion generation was 994.5 ea/cm^3, and the momentary minimum anion generation was 625.9 ea/cm^3. According to DMRT analysis, the average

Table 4. Corrletaion between weather and anion by photosynthetic inactivity

			Anion	Solar radiation	Temperature	Relative humidity
U	Solar radiation	C.C[z]	-.265			
		P value	.460			
	Temperature	C.C	.340	.695*		
		P value	.337	.026		
	Relative humidity	C.C	-.159	-.518	-.774**	
		P value	.661	.125	.009	
	Wind speed	C.C	.204	-.148	-.079	-.263
		P value	.572	.682	.828	.464
M	Solar radiation	C.C	-.342			
		P value	.333			
	Temperature	C.C	-.781**[y]	.779**		
		P value	.008	.008		
	Relative humidity	C.C	.834**	-.597	-.961**	
		P value	.003	.068	.000	
	Wind speed	C.C	-.168	.501	.198	-.087
		P value	.642	.140	.584	.812
L	Solar radiation	C.C	.172			
		P value	.635			
	Temperature	C.C	.299	.466		
		P value	.402	.175		
	Relative humidity	C.C	-.069	.067	.457	
		P value	.849	.854	.184	
	Wind speed	C.C	.675*[x]	.194	-.269	-.611
		P value	.032	.591	.453	.061

[z]. C.C = Coefficient of correlation
[y]. ** = The correlation of coefficient is significant at the 0.01 level
[x]. * = The correlation of coefficient is significant at the 0.05 level

significant difference between the locations was around 0.05 difference (Fig. 3.).

The analysis of the correlation of weather factors and anion generation was as thus. For U Location, there proved to be no correlation with any weather factors. As for M Location that saw the most anion generation, it saw the same correlation with the active photosynthesis periods in which it saw positive correlation with relative humidity and negative correlation with temperature. As for L Location, it saw positive correlation with wind velocity while seeing no other relation with any other weather factors (Table 5).

3.3. Anion generation due to vertical structures

By analyzing the anion generation caused by vertical structure of trees. The average anion generation during active photosynthesis periods was 658.5 ea/cm^3 and the average anion generation during dormant photosynthesis periods was 1035.7 ea/cm^3

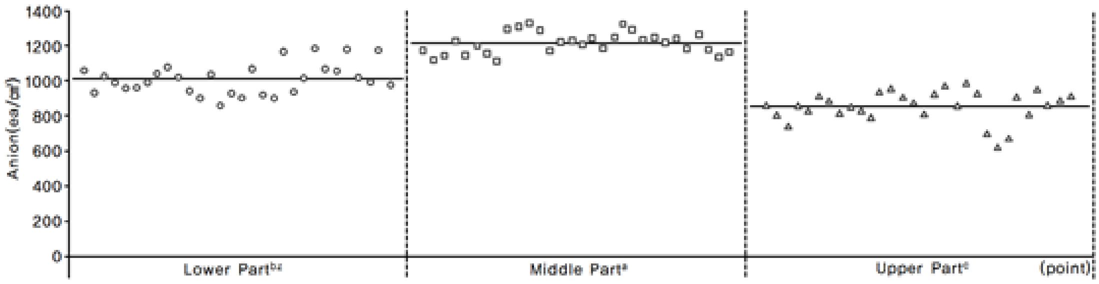

Fig. 3. Measurement points of anion generation at photosynthetic inactivity z. Different letters in the same column indicate a significant difference at P < 0.05 according to Duncan's multiple range test.

all three locations saw higher generation during the dormant period (Fig. 4).

weather factors and anion generation, the results were as thus. During active photosynthesis periods, anion generation showed negative correlation with solar radiation and saw negative correlation with wind velocity. During dormant photosynthesis periods, anion generation showed negative correlation with solar radiation and temperature and positive correlation with relative humidity and wind velocity.

By conducting multiple regression analysis to see the correlation between weather factors and anion

Table 5. Corrletaion between weather and anion by photosynthetic activity and inactivity

			Anion	Solar radiation	Temperature	Relative humidity
P.A[z]	Solar radiation	C.C[x]	-.217[*w]			
		P value	.040			
	Temperature	C.C	.067	.459**		
		P value	.532	.000		
	Relative humidity	C.C	-.099	-.381**	-.935**	
		P value	.353	.000	.000	
	Wind speed	C.C	.565[**x]	-.393**	-.270*	.083
		P value	.000	.000	.010	.438
P.I	Solar radiation	C.C	-.408*			
		P value	.025			
	Temperature	C.C	-.616**	.839**		
		P value	.000	.000		
	Relative humidity	C.C	.446*	-.537**	-.662**	
		P value	.013	.002	.000	
	Wind speed	C.C	.701**	-.484**	-.690**	.241
		P value	.000	.007	.000	.200

[z]. P.A = Photosynthetic activity, P.I = Photosynthetic inactivity
[y]. C.C = Coefficient of correlation
[x]. ** = The correlation of coefficient is significant at the 0.01 level
[w]. * = The correlation of coefficient is significant at the 0.05 level

Table 6. Result of multiple regression analysis by photosynthetic activity

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	512.070	27.900		18.354	.000		
	Wind speed	282.443	44.009	.565	6.418	.000	1.000	1.000
2	(Constant)	.983	192.979		.005	.996		
	Wind speed	314.337	44.186	.628	7.114	.000	.927	1.079
	Temperature	16.913	6.324	.236	2.675	.009	.927	1.079
3	(Constant)	-2846.934	1050.85		-2.709	.008		
	Wind speed	381.216	49.040	.762	7.774	.000	.700	1.429
	Temperature	68.429	19.677	.956	3.478	.001	.089	11.233
	Relative humidity	18.294	6.643	.731	2.754	.007	.095	10.486

generation, results showed that there were three models during the active photosynthesis periods. On the other hand, in the case of Model 3, collinearity statistics' average difference of temperature and relative humidity was less than 1, however as VIF figures showed 11.233 and 10.486 respectively, it was deemed that multiple regression analysis was no appropriate (Table 6).

Multiple regression analysis for the active photosynthesis periods' prediction of weather factors and anion generation is as follows.

Y_1 indicates Model 1's anion generation prediction according to the multiple regression analysis, while X_1 means the wind velocity's experimental value. Here, the coefficient of determination R^2 .311 was interpreted as 31.1%. Also, Y_2 is Model 2 prediction of anion generation in which X_2 is the temperature's experimental value. Here also, the coefficient of determination R^2 .371 was interpreted as 37.1% (Eq. 1).

$$\begin{aligned} Y_1 &= 282.443X_1 + 512.07 \\ Y_2 &= 314.337X_1 + 16.913X_2 \end{aligned} \tag{1}$$

Y_1 is the multiple region analysis' Model 1, and just as the positive photosynthesis periods, X_1 is the experimental value of wind velocity. Y_2 represents Model 2, and X_2 is the experimental value of relative humidity. The coefficient of determination R^2 for Model 1 and Model 2 are .491, .573, both of which were interpreted into 49.1% and 57.3% (Eq. 2).

$$\begin{aligned} Y_1 &= 391.009X_1 + 840.043 \\ Y_2 &= 351.412X_1 + 32.765X_2 \end{aligned} \tag{2}$$

Table 7. Result of multiple regression analysis by photosynthetic inactivity

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	840.043	44.782	.701	18.758	.000		
	Wind speed	391.009	75.244		5.197	.000	1.000	1.000
2	(Constant)	-1113.28	859.719		-1.295	.206		
	Wind speed	351.412	72.319	.630	4.859	.000	.942	1.061
	Relative humidity	32.765	14.404	.295	2.275	.031	.942	1.061

Dormant photosynthesis periods showed two models; neither had any problem with collinear statistics (Table 7). Multiple regression analysis' results are as follows.

4. Conclusions and Discussion

By using a single tree's vertical structure rather than analyzing an expansive green space to measure anion generation in relation to weather factors, active photosynthesis periods' solar radiation was at its lowest in the M Location due to the solar shading caused by leaves. For relative humidity, U and M :Locations that produced the most transpiration, produced less than L Location as L Location was surrounded by earth and grass that produced additional production.

During dormant photosynthesis periods, anion generation was lowest in the U Location; this is attributed to *Zelkova Serrata*'s physiological traits that have adapted to the environment to have relatively low physiological activity in upper leaves and branches (Kim, 2003). The reason for the high standard error was as solar radiation increased, outer temperature rose leading to an increase in ion diffusion coefficient that affected the result (Lee et al., 1998). Also, according to the correlation in U Location, the reason for the positive correlation with temperature and negative correlation with relative humidity is that higher areas have higher solar radiation and temperature making it so that the tree's physiological reactions cannot affect the anion generation. However when air temperature was continuously rising, anions and temperature showed positive correlation resulting in the equal conclusion (Baron and Wand, 1983); this was similar to the report about anion generation, which stated that anion radiation has a positive correlation with light intensity and relative humidity (Shin et al., 2012). For the M Location, the reason for the positive correlation for relative humidity and wind speed was that the tree's stomata transpiration or evaporation around the stoma was affecting the anion generation (Hopkins and Huner, 2006; Wei et al., 2006; Wu et al., 2006). For the L Location, anion generation was expanded by the evapotranspiration of earth and grass that was affected that the solar radiation and wind speed.

As for the weather factors during the dormant photosynthesis periods, solar radiation was studied by comparing the U location and L Location, which indicated a 79.4% blockage solar blockage rate; this symbolizes that 80% of solar radiation is absorbed by the trees leaving only 20% to pass through, which comes to a similar result as with a previous paper (Kim, 1988). Temperature showed a disparity between the high and low parts of the tree by 2.2, which showed temperature decrease in 6.5%. Relative humidity was highest in the L Location, and this is analyzed to have been the result of earth related issues as seen in the active photosynthesis periods.

U Location saw both the highest solar radiation and temperature in both the active photosynthesis periods and the dormant period, but had the least anion generation; this shows that high temperature and solar radiation disturbed the tree's natural physiological process. By analyzing the M Location's anion generation, despite general notion that a day's highest temperature occurs during the dormant photosynthesis periods, the tree's solar shading created a lower temperature than the outer conditions, which vitalized the physiological process. As mentioned before, the earth and grass' evapotranspiration has affected L Location anion radiation. Seeing that average anion generation during the dormant photosynthesis periods is the highest, the weather factors in the M Location during the dormant photosynthesis periods can see seen as the ideal environment for the most anion generation.

Seeing that the average anion generation difference between the two photosynthesis periods was 377.2

ea/cm^3 with dormant photosynthesis periods being on top, it become evident that a tree's physiological process little effect on influencing the outcome, rather it is the external environmental factors that are influential. Furthermore, active photosynthesis periods measured 83.0 W/m^2 in average solar radiation, 29.8 in temperature, 71.3% in average relative humidity, 0.14 m/s in average wind speed. On the other hand, dormant photosynthesis periods measured 84.5 W/m^2 in average solar radiation, 32.4 in temperature, 60.2% in average relative humidity, 0.50m/s in average wind speed. These measurements was similar to a previous paper that stated that anion generation was highest when the temperature was between 31 and 35 and the relative humidity is between 60% and 70% (Kim et al., 2012; Tammet et al., 2006). Also, seeing that correlation between weather factors and anion production was different for locations and each photosynthesis periods, the effects that weather factors have on anion generation is different depending on the time and location. According to the multiple regression analysis for the correlation between weather factors and anion generation, two models each for active and dormant photosynthesis periods could be constructed and as the Model 2 of the dormant photosynthesis period has a R^2 of 57.3% this model was deemed to be the most suitable.

This research was limited by the lack of quantizing a tree's physiological activity and instead estimating according to time flow. However, the value of this research lies in measuring anion generation's relation to weather conditions according to a singular tree's vertical structure. Further research through quantizing a tree's physiological activity in order to more clearly define the relationship between weather factors and physiological process of trees in needed.

Acknowledgements

This paper was supported by Konkuk University.

REFERENCES

Baron, M. J., Wand, R. H., 1983, Fregion ion temperature enhancements resulting from joule heating, J. Geophysical Research, 88, 4114-4118.

Buckalew, L. W., Rizzuto, A., 1982, Subjective response to negative air ion exposure, Aviation, space, and Environmental Medicine.

Hopkins, W. G., Hüner, N. P. A., 2006, Plant physiology, World Science.

Ji, C. K., 2003, Effect of anion, Seoul of Korea, Living books.

Ji, C. K., 2005, Air pollution and anion, Korean Institute of Illuminating and Electrical Installation Engineers, 19(3), 3-9.

Jo, Y. B., 2010, A study on the development of suitable locations evaluation model and therapy type to therapeutic forest, M. S. Thesis., Wonkwang University, Iksan, Jeonbuk, Korea (in Korean with English abstract).

Karjalainen, E., Sarjala, T., Raitio, H., 2010, Promoting human health through forest: Overview and major challenges, Environmental Health and Preventive Medicine, 15(1), 1-8.

Kim, H. S., 2003, Ecophysiological characteristics of long and short shoots in Zelkova serrata, Cheongju University, Cheongju, Chungbuk, Korea (in Korean with English abstract).

Kim, J. H., Oh, D. K., Yoon, Y. H., 2012, An analysis of anions distribution and correlation by biotope types in summer for pleasant urban environment, Urban Design Institute of Korea, 13(1), 51-62.

Kim, K. H., Shin, W. S., Yeoun, P. S., Lee, J. H., 2012, Amount of negative ions by forest climates, Korea Institute of Forest Recreation Welfare, 16(4), 125-131.

Kim, K. S., 1998, Agricultural Meterology, Korea, Hyangmunsa.

Kim, S. K., Shin, W. S., Kim, M. K., Yeoun, P. S., Park, J. H., Yoo, R. W., 2008, The effect of negative ions on stress responses and cognitive functions, J. korean forest society, 97(4), 423-430.

Krueger, A. P., 1985, The biological effects of air ions, Int. J. Biometeorology, 29(3), 205-206.

Lee, D. H., Chae, Y. G., Jun, J. H., Yoon, T. K., Lee, M.

G., 1998, Temperature effect on the nitrate removal by anion - Exchange resin, The Korean Society of Industrial Enginneering Chemistry, 2(2), 885-888.

Luts, A., Salm, J., 1994, Chemical composition of small atmospheric ions near the round, J. Geophys Res., 99(D5), 10781-10785.

Nam, H. I., 2013, A Study on anion concentration in relation to forest type, topography and altitude, M. S. Thesis, Sangji University, Wonju, Gangwon, Korea (in Korean with English abstract).

Perkins, M. D., Eisele, F. L., 1984, Irst mass spectrometric measurements of atmospheric ions at ground level, J. Geophys Res., 89(D6), 9649-9657.

Rho, S. K., Kim, H. L., 2007, Effects of O_2 and minus ion treatment on oxidant and anti-oxidant enzymes activity during maximal GXT in men and women, The Official Journal of the Korean Association of Certified Exercise Professionals, 9(1), 59-67.

Skalny, J. D., Mikoviny, T., Matejcik, S., Mason, N. J., 2004, An analysis of mass spectrometric study of negative ions extracted from negative corona discharge in air, Int. J. Mass Spectrum, 233, 317-324.

Shin, W. S., Yeoun, P. S., Kim, K. H., Lee, J. H., 2012, Amount of a negative ions by forest climates, Journal of Korea Institute of Forest Recreation Welfare, 16(4), 125-131.

Tammet, H., Horrak, U., Laakso, L., Kulmala, M., 2006, Factors of air ion balance in a coniferous forest according to measurements in Hyytiälä, Finland, Atmospheric Chemistry and Physics, 6(11), 3377-3390.

Um, T. W., Kim, G. T., 2010, Correlations between concentrations of negative ions and forest type and site factors at national forests in Yangyang-gun, Korean Society of Environment and Ecology, 24(5), 539-546.

Wei, C., Wang, J., Jiang, Y., Zhang, Q., 2006, Air negative charge ion concentration and its relationships with meteorological factors in different ecological functional zones of Hefei city, The Journal of Applied Ecology, 17(11), 2158-2162.

Wu, C. C., Lee, G. W., Yang, S., Yu, K. P., Lou, C. L., 2006, Influence of air humidity and the distance from the source on negative air ion concentration in indoor air, Science of the Total Environment, 370(1), 245-253.

Yataki, K., 1993, The power of forest, Tokyo of Japan, Kobun-sa.