The Effect of pH from Simulated Acid Rain on Multi- Element Contents of Leaves, Stems and Roots of the Crops

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(Received, December 21, 2005)

Abstract

In this study, simulated acid rain in which the pH differs was sprinkled on crops for 1 week. The concentrations of Mg, Ca, K, P , Fe and Zn in the leaves, stems and roots of these crop plants was determined by ICP atomic emission spectrometry. As a result, it was shown that many elements were easily released from the crops, as the pH was lowered. However, it became clear that Fe ion was very easily absorbed by each part of the plant at pH 5.6, though the level was decreased at pH 4.7 or less.

Keywords: leaf, stem and root of crops, essential element, inorganic ion, simulated acid rain

1. Introduction

Recently, forest have withered due to acid rain or acidic mist, and the effect on cultural assets has become a large social problem. Cases in which the soil has become acidified[1-8] and cases in which acid rain directly falls on the plant[9-14] are considered the path ways by which plants are affected by acid rain. Extensive research on plant growth and the absorption, storage and release of ions has examined the effect of acidified soil[1-8]. Regarding the direct effect of acid rain falling on plants, however, only research on the yield point of crops has been carried out[9-14]. It is known that organic substances and inorganic ions like calcium and potassium are released from each part of the plant by rain[3]. However, there is limited research on these effects of acid rain at various pH levels[2,3]. Therefore, Kaiware daikon (radish: Raphnus sativus), Alfalfa (pulse :Medicago sativa) and Tohmyo (pea: Pisum sativum) grown from a plant height of several cm to about 10 cm as an experimental crop were used this study. During germination and growth of these crops, simulated acid rain of various pH levels were sprinkled on these seeds and the seedlings were grown for one week. Magnesium (Mg), calcium (Ca), potassium (K), phosphorus (P), iron (Fe) and zinc (Zn) concentrations in each part of the leaf, stem and root of these crops were measured by inductively coupled plasma atomic emission spectrometry (ICP -AES).

As a result, it is reported, data were obtained showing a relationship between the concentrations of ions in the crop and the pH of simulated acid rain.

2. Experimental design

2.1 Formation of simulated acid rain

Simulated acid rain for this study was prepared by dissolving known quantities[3] of various salts in pure water, and the solutions containing salt were respectively adjusted using inorganic acid to pH 5.6, 4.7, 4.0 and 3.5.

2.2 Growth and decomposition procedure of the crops

Rainfall test equipment of simulated acid rain used during germination and growth of crops is shown in Fig.1. Panel.1 of Fig.1 shows a thin plastic vessel (base area: 47.8 cm^2 10 heights cm) with 30 empty holes measuring about 1 mm diameter. Such containers were sown with 1 to 10g of seed. These crops were grown under 20°C room temperature, 12000Lx optical intensity and about 70% humidity and were sprinkled with simulated acid rain from many holes measuring about 1 mm in diameter as shown in Panel 4 of Fig.1. One cup of water was sprinkled on the crops 4 times at a rainfall speed 140ml /10sec for 1 day. For decomposition of the crop before the measurement, 1g of leaf, stem or root was respective placed in a glass container, and then decomposed by inorganic acids. The resultant plant material was then dissolved in 100ml (10mg/ml) of the pure water. Ions in these sample solution were measured by ICP-AES, after being diluted with pure water 10~100 times.

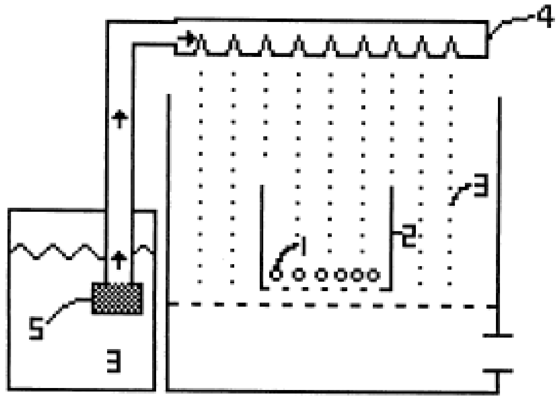

Fig. 1 Rainfall test equipment of simulated acid rain. 1: Seed of crops, 2: plastic vessel, 3: simulated acid rain, 4: simulated acid rainfall equipment, 5: suction pump of simulated acid rain.

3. Result and Discussion

3.1 Amount of rainfall used for the experiment.

The quantity of natural rain over 1 year averages 1800 liters/m^2, namely 1800mm annual. This becomes about 15 mm/day, assuming that rainfall occurs on 1/3 of days (120th) over the year. This experiment used a move severe rain level than natural, as described in 2.2, because the test amount was 117mm of rainfall. However, rainfall of this degree was required using this experimental equipment to prevent the crops from becoming withered

3.2 The effect of the simulated acid rain on multi-element content in each part of the crop plant grown for 1 week.

3.2.1 The effect of simulated acid rain on the germination and growth of crop

The pH of rain differs regionally around the world, and the pH of uncontaminated rain is 5.6. Average pH of recent rain water was 4.7 and in places that are more contaminate the rainfall maybe pH 4~3.5. Therefore, the effect on germination and growth crop of this simulated acid rain was investigated within a range of pH pH 5.6~3.5. The degree of effect on crop growth was represented as a ratio to the sum total of the size of stem and leaf grown at pH 5.6 simulated rain as the standard. Naturally, the standard size differs with the crop. The standard size for Kaiware daikon was 8~11cm. For Alfalfa and Tohmyo, standard sizes were 4~5.5 and 7~9 cm respectively. As a result, there was relatively little the change at pH 4.7. However, there was about 10~25% decrease at pH 4.0 and a sharp decrease of 30~50% at pH 3.5.

3.2.2 The effect of the pH of simulated acid rain water on elemental concentrations in each part of the crop.

At a pH range of 5.6~3.5, elemental concentrations in each part of the crop plants was examined. Mg, Ca, K and P were chosen as macro-component essential elements of the plant and Fe, Zn were chosen as micro-component essential elements[15]. Results of analyses for these 6 elements in each part of 3 kinds of crops grown for one week are shown in Table1~6. Behavior of each macro and micro-component element in grown crop is described below.

1) Macro-component element Mg, Ca, K and P

To begin with, the result for Mg is shown in Table 1. It was shown that the Mg concentration in the leaf of each crop was relatively higher than those in the stem and root, when pH of the simulated acid rain was 5.6. This was especially, remarkable in Kaiware Daikon. However, these differences in Mg concentration could not be seen in Ca, as shown in Table 2. This difference is greatly concerned with photosynthesis. Next, Mg and Ca concentrations decreased to about 30~60% in each part of the plant, when pH was lowered to 4.7. However, Mg and Ca concentrations did not demonstrate further large changes, when pH was lowered to 3.5. Though the reason is not clear, it is thought to be due to the increased hydrogen ion concentration in simulated acid rain, which generated damage to the crop cells, and causing abnormalities in the behavior of these ions.

The result for K is shown in Table 3. In all crops, there was no change in the concentration of K in each part of the plant, and there was no apparent effect at pH 5.6~3.5. Especially, Tohmyo showed remarkable K levels in these crops. The K concentration in the seed is known to be very high. It is considered therefore, that it is not influenced by the hydrogen ion concentration within the range tested. Next, the result for P which showed the highest concentration of the 6 elements in the seed is shown in Table 4. P was compared between the stem and root because the concentration in the leaf was slight, At pH 4.7, there was marked elution generated in the stem and root. However, there was not a large change in P, when pH was

Table 1 The effect of pH of the simulated acid rain for the Mg content in each part place of the crops

Element	Kind of crop	pH of simulated acid rain(pH)	Seed (ppm)	Leaf (ppm)	Stem (ppm)	Root (ppm)
Mg	Kaiware Daikon	5.6	2633	712	107	79
		4.7		779	48	47
		4.0		609	108	54
		3.5		553	59	29
	Alfalfa	5.6	1618	167	80	95
		4.7		111	22	24
		4.0		74	12	42
		3.5		102	35	36
	Tohmyo	5.6	1059	206	133	105
		4.7		101	115	63
		4.0		131	86	72
		3.5		125	81	68

Table 2 The effect of pH of the simulated acid rain for the Ca content in each part place of the crops

Element	Kind of crop	pH of simulated acid rain (pH)	Seed (ppm)	Leaf (ppm)	Stem (ppm)	Root (ppm)
Ca	Kaiware Daikon	5.6	1847	389	337	168
		4.7		463	110	76
		4.0		249	127	149
		3.5		225	88	95
	Alfalfa	5.6	773	75	83	125
		4.7		66	50	65
		4.0		54	36	76
		3.5		49	39	45
	Tohmyo	5.6	509	64	52	92
		4.7		39	26	47
		4.0		32	25	49
		3.5		31	21	46

Table 3 The effect of pH of the simulated acid rain for the K content in each part place of the crops

Element	Kind of crop	pH of simulated acid rain (pH)	Seed (ppm)	Leaf (ppm)	Stem (ppm)	Root (ppm)
K	Kaiware Daikon	5.6	2517	723	678	1078
		4.7		771	607	429
		4.0		681	432	782
		3.5		686	445	449
	Alfalfa	5.6	1641	648	836	602
		4.7		787	492	539
		4.0		393	392	570
		3.5		595	506	613
	Tohmyo	5.6	9249	1037	1151	1164
		4.7		999	1115	817
		4.0		1268	1079	929
		3.5		1184	1048	921

Table 4 The effect of pH of the simulated acid rain for the P content in each part place of the crops

Element	Kind of crop	pH of simulated acid rain (pH)	Seed (ppm)	Leaf (ppm)	Stem (ppm)	Root (ppm)
P	Kaiware Daikon		6690			
		5.6		1016	485	405
		4.7		1126	71	47
		4.0		892	209	135
		3.5		1361	148	101
	Alfalfa		6360			
		5.6		857	644	680
		4.7		657	209	178
		4.0		305	121	155
		3.5		522	260	310
	Tohmyo		3300			
		5.6		941	702	980
		4.7		499	381	339
		4.0		565	402	367
		3.5		529	348	356

below 4.0.

2) Micro component element Fe and Zn

The results for Fe and Zn, which are micro-elements, are respectively shown in Table 5 and Table 6. Fe concentration in the seed is very low. However, Fe in each part of plants grown at pH 5.6 showed a several-fold higher concentration compared with that in the seed. It was shown that Fe was very easily absorbed to the crop, though many elements examined here were released from each part place. However, Fe concentrations in each part rapidly decreased, when pH of the simulated rain water decreased below 4.7. Especially, in Tohmyo, when the pH was 3.5, Fe was only slightly detected, and the effect of acid rain on Fe was noticeable. In the case of Zn, there was a similar low concentration in the seed of each crop, equivalent to that of Fe.

Table 5 The effect of pH of the simulated acid rain for the Fe content in each part place of the crops

Element	Kind of crop	pH of simulated acid rain (pH)	Seed (ppm)	Leaf (ppm)	Stem (ppm)	Root (ppm)
Fe	Kaiware Daikon		92			
		5.6		336	294	299
		4.7		45	32	26
		4.0		28	19	24
		3.5		36	16	15
	Alfalfa		78			
		5.6		316	286	290
		4.7		37	29	34
		4.0		40	34	63
		3.5		29	6	8
	Tohmyo		183			
		5.6		299	289	285
		4.7		11	8	12
		4.0		13	7	13
		3.5		12	6.5	11

Table 6 The effect of pH of the simulated acid rain for the Zn content in each part place of the crops

Element	Kind of crop	pH of simulated acid rain (pH)	Seed (ppm)	Leaf (ppm)	Stem (ppm)	Root (ppm)
Zn	Kaiware Daikon		49			
		5.6		0.68	0.13	0.44
		4.7		-	-	-
		4.0		-	-	-
		3.5		-	-	-
	Alfalfa		51			
		5.6		1.2	-	0.42
		4.7		-	-	-
		4.0		-	-	-
		3.5		-	-	-
	Tohnyo		37			
		5.6		6.2	2.4	1.7
		4.7		-	-	-
		4.0		-	-	-
		3.5		-	-	-

- : not detected

However, Zn was completely undetectable in from each part of the crop, when the pH was 4.7 or less. Therefore, it became clear that Zn was very easily affected by acid rain.

4. Conclusion

Simulated acid rain water in this experiment contained quantities of inorganic components similar to these in natural rain water, and the pH range changed from 5.6 to 3.5. Using the simple equipment shown in Fig.1, the experimental crops were sprinkled with simulated acid rain at these pH levels, at several times the natural amount of rainfall on crops at this growth stage in order to prevent plant death due to water shortage. Therefore, the result is understood to represent the effect of natural acid rain. However, it is expected that the pH of acid rain will decrease below pH 4.7 in the future[3]. And, an increased amount of rainfall based on global warming is also estimated. Therefore, the data obtained here is expected to be useful in expanding our knowledge of environmental science.

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