CHAPTER 3

RESULTS

This chapter presents the results from actual observation and measurement of rainwater, soil and plants in the laboratory. The results were analysed by ANOVA.

3.1 Percentage seed germination

Rice, cucumber, pole bean and tomato were germinated after three days of seed sowing, except tobacco that germinated after 7 days of sowing and the end of germination in twenty one days.

Pole bean had the highest percent seed germination, while tobacco had the lowest. The lowest seed germination was found in the treatment with simulated acid rainwater having the lowest pH at pH 2.0, in particular tobacco.

Three species rice, pole bean and tomato showed significant differences among treatments at the 0.05 level and their p value were 0.011, 0 and 0.024, respectively. Rice showed higher percent germination in control treatment and pH 2.0 than pH 2.5, pH 3.0, pH 5.0 and pH 4.0. Pole bean showed lower percent germination in pH 2.0 than control treatment, pH 5.0, pH 4.0, pH 3.0 and pH 2.5. While tomato showed higher percent germination in control treatment and pH 5.0 than pH 2.5 and pH 2.0. Two species, cucumber and tobacco showed no significant differences between treatment at the 0.05 level and p value were 0.075 and 0.079, respectively. Five plants species showed significant difference among species at p value less than 0.05. (Table 3.1).

Table 3.1 Mean of percent seed germination twenty one days after sowing

Plants	Mean ± S.D. of percentage seed germination							
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.5	pH 2.0	F-Value	Species mean
Rice	84.60± 8.50a	61.80± 25.38b	60.20± 5.26b	63.4± 8.26b	64.60± 8.41b	81.20± 3.70a	0.011	69.30± 10.69b
N	5	5	5	5	5	5		30
Cucumber	50± 7.07ns	60± 7.87ns	60± 5.09ns	57.20± 10.26ns	61.60± 7.27ns	47.20± 12.85ns	0.075	56± 5.97c
N	5	5	5	5	5	5		30
Pole bean	95.33± 4.47a	93.33± 4.72a	98± 1.83a	94± 6.41a	94± 5.48a	70± 12.69b	0.00	90.78± 10.31a
N	5	5	5	5	5	5		30
Tomato	84.60± 9.13a	84± 11.25a	78± 6.52ab	73.80± 7.56ab	71.80± 8.50b	69± 3.16b	0.024	76.87± 6.46b
N	5	5	5	5	5	5		30
Tobacco	55± 7.57ns	64.6± 43.04ns	57.10± 39.26ns	53.90± 14.13ns	36.30± 5.86ns	19.30± 1.82ns	0.079	47.70± 27.40c
N	5	5	5	5	5	5		30
Treatment mean	73.91± 20.10ns	72.75± 14.99ns	70.66± 17.38ns	68.46± 16.16ns	65.66± 20.74ns	57.34± 24.57ns	0.777	68.13± 18.40
N	25	25	25	25	25	25		150
F-value								0.000

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.2 Plant growth rates

1) Height

The measurement of plants height were recorded at 120 days after seedlings. Pole bean had higher growth than the other plants, while tobacco had the lowest growth. The treatment at pH 5.0 had highest growth rate while pH 2.0 had lowest (Table 3.2).

The mean growth of pole bean in terms of height in all pH treatments was significantly higher at the 0.05 level than other plants. Only rice and tomato showed significant differences among the treatments, while cucumber, pole bean and tobacco showed no significant different among all treatments at the 0.05 level. Rice treated in the control, pH 2.0 and pH 2.5 treatment grew significantly taller than rice subjected to pH 5.0 and pH 3.0. Tomato treated with pH 5.0 grew significantly shorter than with the control, pH 4.0, pH 3.0, pH 2.5 and pH 2.0 at the 0.05 level (p value was 0.008). Therefore, pH had no significant effect on growth of three out of five species (Table 3.2).

Table 3.2 Mean of plants height (cm.)

Plants	Mean ± S.D. of plants height (cm.)							
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.5	pH 2.0	F-value	Species mean
Rice	82.44± 7.07a	78.12± 10.45c	81.12± 8.21b	79.88± 6.83c	95.64± 7.17a	89.44± 4.51a	0.009	84.40± 6.73b
N	5	5	5	5	5	5		30
Cucumber	90.68± 12.36ns	85.56± 7.39ns	87.3± 13.27ns	90.15± 14.47ns	91.38± 18.54ns	95.99± 6.7ns	0.845	90.18± 3.61b
N	5	5	5	5	5	5		30
Pole bean	176.34± 49.13ns	226± 25.08ns	164.23± 89.87ns	169.4± 65.5ns	170.68± 78.88ns	110.95± 49ns	0.180	169.6± 36.60a
N	5	5	5	5	5	5		30
Tomato	83.76± 8.31a	74.18± 3.11b	82.68± 8.66a	84.69± 11.55a	87.48± 7.15a	104.75± 6.72a	0.008	84.2± 10.25b
N	5	5	5	5	5	2		27
Tobacco	40.92± 5.17ns	30.20± 8.15ns	30.96± 9.60ns	38.88± 15.65ns	39.52± 5.57ns	41.52± 5.58ns	0.208	37± 5.07c
N	5	5	5	5	5	5		30
Treatment mean	94.83± 49.61ns	98.81± 74.32ns	89.26± 47.78ns	92.60± 47.47ns	96.94± 47.06ns	88.53± 27.53ns	0.999	93.49± 46.39
N	25	25	25	25	25	22		147
F-value								0.000

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

2) Fresh weight of plant

The measurement of fresh weight of plants were recorded at 120 days after seedling. Pole bean had higher fresh weight than the other plants, while rice had the lowest fresh weight. The control treatment for three of the species, cucumber, pole bean and tobacco resulted in higher fresh weights than the other treatments, while rice and tomato had higher fresh weights with the pH 2.5 and pH 2.0 treatments, respectively.

All plant species except tobacco showed significant differences in fresh weight among the treatments at the 0.05 level. Rice produced the highest fresh weight at pH 2.5 at the 0.05 level, while cucumber had highest fresh weight with the control treatment, pH 5.0 and pH 2.0 than the other treatments. Pole bean had highest fresh weight with the control treatment and tomato had highest at pH 2.0. Tobacco showed no significant differences among treatment at the 0.05 level and p value was 0.205 (Table 3.3).

Table 3.3 Mean of individual plants fresh weights (g.)

Plants	Mean ± S.D. of plants fresh weights							
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.5	pH 2.0	F-value	Species mean
Rice	3.08± 0.56b	3.06± 0.55b	2.84± 0.36b	3.40± 0.20b	4.40± 0.25a	2.56± 0.30b	0.000	3.22± 0.69b
N	5	5	5	5	5	5		30
Cucumber	12.89± 3.80a	10.15± 2.46a	7.51± 2.39b	7.36± 0.39b	9.85± 0.30b	11.28± 1.81a	0.004	9.84± 2.84a
N	5	5	5	5	5	5		30
Pole bean	13.03± 2.04a	10.52± 0.60b	9.64± 0.98b	9.12± 0.74b	10.84± 0.83b	9.04± 2.22b	0.001	10.36± 0.88a
N	5	5	5	5	5	5		30
Tomato	4.68± 0.45c	3.38± 0.50d	4.76± 0.43c	6.38± 1.03b	4.84± 0.42c	14.25± 3.18a	0.000	5.49± 2.82ab
N	5	5	5	5	5	2		27
Tobacco	11.43± 1.72ns	6.28± 2.44ns	10.82± 6.56ns	7.32±4.18ns	8.48± 2.13ns	7.92± 1.95ns	0.205	8.71± 3.77a
N	5	5	5	5	5	5		30
Treatment mean	9.02± 4.77	6.66± 3.58	7.11± 3.32	6.72± 2.10	7.68± 2.92	9.01± 4.34	0.811	7.70± 3.44
N	25	25	25	25	25	22		147
F-value								0.000

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.3 Crop yield

The plants produced yields under most treatments, even when watered with rainwater with low pH. However, plant species such as rice, pole bean, tomato and cucumber treated with pH 2.0 produced lower yields than the other treatments. While plants treated with pH 2.5 and above 2.5 had productions similar to the group treated with normal rainwater (Figure 3.1)

There was significant differences in rice in different treatments at the 0.05 level while there were no significance in all treatment (Table 3.4).

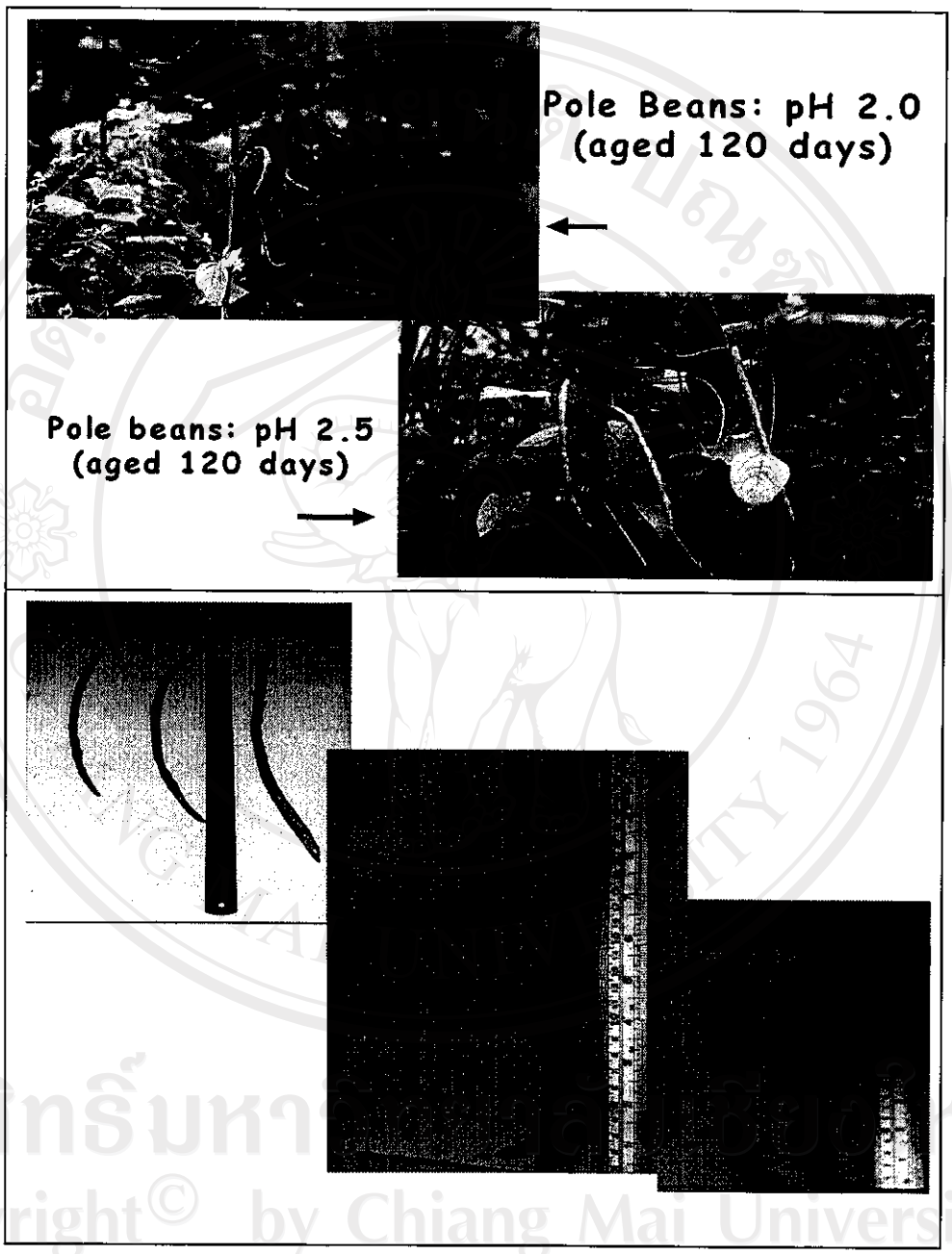

Figure 3.1 Yields of pole bean in the study that treated with different pHs

Table 3.4 Mean of yield number (rice : number of grain, cucumber, pole bean and tomato : number of ripen fruit)

Plants	Mean ± S.D. of yields number							
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.5	pH 2.0	F-value	Species mean
Rice	67.12± 9.96b	46.63± 8.09c	46.02± 8.95c	98.66± 50.25a	100.80± 21.38a	62.56± 13.08b	0.002	70.30± 31.28
N	5	5	5	5	5	5		30
Cucumber	7.60± 3.29ns	5.00± 3.08ns	4.00± 1.58ns	3.60± 1.95ns	7.20± 2.77ns	3.40± 2.30ns	0.053	5.13± 2.90
N	5	5	5	5	5	5		30
Pole bean	6.50± 2.65a	4.00± 1.87b	6.60± 5.90a	5.20± 3.70ab	4.60± 3.65b	1.80± 1.30c	0.033	4.72± 3.61
N	4	5	5	5	5	5		29
Tomato	1.50± 0.71ns	2.75± 1.71ns	3.33± 0.58ns	3.00± 0ns	2.00± 0bns	1.00± 0ns	0.218	2.40± 1.18
N	2	4	3	2	2	2		15
Treatment mean	20.68± 31.07ns	14.60± 21.38ns	14.99± 20.74ns	27.62± 47.37ns	28.65± 48.15ns	17.19± 30.26ns	0.811	20.62± 31.46
N	16	19	18	17	17	17		104

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.4 Visible impact on plants

Some impact occurred on most plants watered with low pH simulated rainwater (pH 2.0 and pH 2.5). Visible signs of damage included 1) necrosis 2) white, black and brown spots and 3) abnormal shapes (Figure 3.2 and 3.3). Signs of damage occurred on leaves, stems, flowers and yields (Figure 3.4). Necrosis was found on leaves, while white, black and brown spots were found on leaves, stems flowers and yields.

Figure 3.2 White spots in pole bean plant treated with pH 2.0 (aged 21 days)

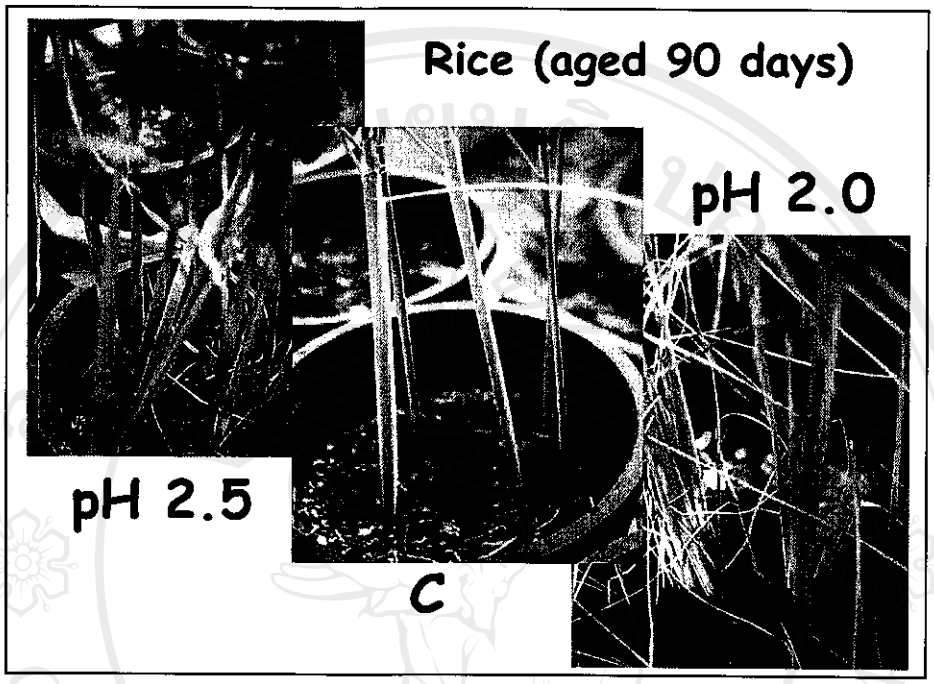

Figure 3.3 Brown spots on stems of rice (aged 90 days)

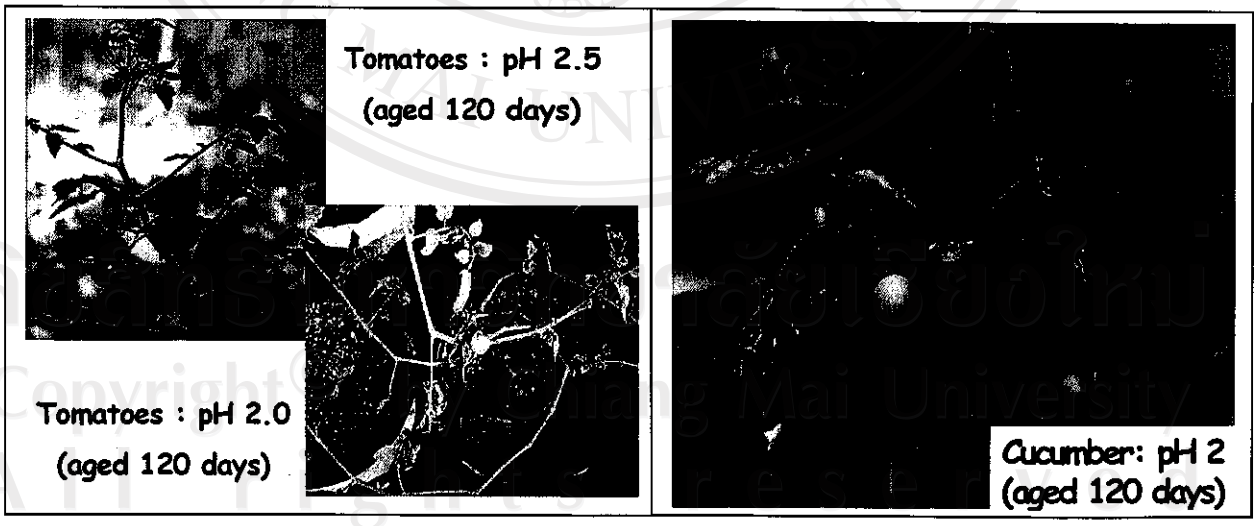

Figure 3.4 Abnormal shapes of yields of tomato and cucumber

3.5 Results of rainwater analysis

3.5.1 pH and EC of rainwater

1) Normal rainwater

The pH of rainwater averaged between 6.7 to 7.1. The EC value of rainwater was higher at sites 3 and 4 than at sites 1 and 2, since sites 1 and 2 were open and sites 3 and 4 the water were collected from the cement roof. The values ranged between 17.6 to 66.4 μS/cm.

There were no significant differences in pH among all sites. For EC, site 3 was higher significantly than at site 4, site 1 and site 2. There were significant differences at the 0.05 level (Table 3.5).

Table 3.5 pH and EC in normal rainwater

Parameter	Mean ± S.D. of pH and EC in normal rainwater					
	Site 1	Site 2	Site 3	Site 4	F-value	Mean
pH	6.86± 0.45ns	6.70± 0.20ns	7.11± 0.80ns	6.96± 0.32ns	0.387	6.95± 0.52
N	26	3	17	23		69
EC (μS/cm)	28.41± 13.00b	17.60± 0.70b	66.4± 28.80a	53.5± 21.50ab	0.00	45.67± 31.23
N	26	3	17	23		69

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

2) Simulated rainwater

Normal rainwater with an average pH at 7.1 was used to make the simulated rainwater. The pH of simulated rainwater was adjusted to 2.0, 2.5, 3.0, 4.0 and 5.0 by sulfuric acid. The EC value of normal rainwater was 62.52 μS/cm. The EC of simulated rainwater increased as the pH was decreased. The values ranged from 77.95 to 5,015 μS/cm .

All pHs treatments of rainwater produced significant differences at p 0.05 level. EC of simulated rainwater treated with pH 2.0 was highest while lowest EC values were obtained with the control treatment. However, control treatment, simulated rainwater with pH 5.0 and pH 4.0 were not different at the 0.05 level. Simulated rainwater with pH 3.0, pH 2.5 and pH 2.0 were significant differences at the 0.05 level (Table 3.6)

Table 3.6 pH and EC in simulated rainwater

Parameter	Mean ± S.D. of pH and EC in simulated rainwater						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.5	pH 2.0	F-value
pH	7.1± 0.22a	5.02± 0.05b	4.03± 0.05c	3.01± 0.03d	2.52± 0.02e	2.01± 0.02f	0.00
N	4	4	4	4	4	4	
EC (μS/cm)	62.52± 4.90d	77.93± 2.8d	118.25± 10.97d	534.25± 10.43c	1,759± 55.68b	5,015± 130.47a	0.00
N	4	4	4	4	4	4	

Remark : Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.5.2 Cations and anions in rainwater

1) Cations in rainwater

1.1) Normal rainwater

Natural rainwater from the open area (sites 1 and 2) had lower concentrations of cations and anions than rainwater from at sites 3 and 4. Concentrations of Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+} ranged between 0.652-1.123, 0.498-0.918, 0.668-2.921, 0.058-0.111, 1.796-7.703 ppm, respectively. While the concentration of Cl^-, NO_3^- and SO_4^{2-} ranged between 0.645-1.110, 0.411-0.936, 0.905-2.047 ppm, respectively.

Sites 3 and 4 had highest Ca^{2+}, while sites 1 and 2 had lowest Ca^{2+}. There were significant differences among the sites only for concentrations of Ca^{2+} at sites 3 and 4 at the 0.05 level, while the other cations showed no significant differences among all sites (Table 3.7).

Table 3.7 Cations concentrations in normal rainwater (ppm)

Cations	Mean ± S.D. of cations concentrations in normal rainwater				
	Site 1	Site 2	Site 3	Site 4	F-value
Na^+	1.09± 0.98ns	0.65± 0.38ns	0.99± 0.51ns	1.12± 0.97ns	0.569
N	15	10	13	15	
NH_4^+	0.08± 0.06ns	0.06± 0.05ns	0.11± 0.05ns	0.11± 0.08ns	0.467
N	15	10	13	15	
K^+	1.48± 1.71ns	0.67± 1.04ns	2.99± 1.41ns	2.92± 4.30ns	0.174
N	15	10	13	15	
Mg^{2+}	0.08± 0.06ns	0.06± 0.05ns	0.11± 0.05ns	0.11± 0.08ns	0.328
N	15	10	13	15	
Ca^{2+}	2.23± 3.22b	1.80± 2.66b	7.96± 4.38a	7.70± 3.16a	0.00
N	15	10	13	15	

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

1.2) Cations in simulated rainwater

Concentrations of cations in simulated rainwater and the control were very different. Na^+, NH_4^+, K^+, Mg^{2+}, and Ca^{2+} in simulated rainwater ranged between 0.59-0.85, 0.04-2.50, 2.64-3.44, 0.01-0.11, 8.50-11.24 ppm, respectively, while the control treatment contained Na^+, Mg^{2+}, and Ca^+ at concentrations of 0.54, 0.14, and 7.91 ppm, respectively.

Na^+ and Mg^{2+} in the control treatment was higher than in the other treatments and there were significant differences at the 0.05 level.

NH_4^+ and Ca^{2+} were highest in the treatments with pH 2.0 and there were significant differences at the 0.05. However, K^+ concentration showed no significant differences among the treatments at pH 3.0, pH 4.0 and pH 5.0, while the control treatments and the treatments with pH 2.0 had lower K^+ and there were significant differences among treatments at the 0.05 level (Table 3.8).

Table 3.8 Cations concentrations in simulated rainwater (ppm)

Cations	Mean ± S.D. of cations in simulated rainwater					
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value
Na^+	0.54± 1.14b	0.61± 0.09a	0.56± 0.18a	0.63± 0.16a	0.85± 0.68a	0.00
N	11	19	19	19	19	
NH_4^+	0± 0c	0.01± 0.02c	0± 0c	0.22± 0.12a	1.97± 1.39b	0.00
N	11	19	19	19	19	
K^+	0± 0c	2.72± 0.34b	2.64± 0.63b	2.86± 0.56b	3.44± 1.18a	0.00
N	11	19	19	19	19	
Mg^{2+}	0.14± 0.04a	0.01± 0.01b	0.01± 0.01b	0.02± 0.04b	0.01± 0.05b	0.00
N	11	19	19	19	19	
Ca^{2+}	7.90± 0.86b	8.65± 0.64b	8.50± 0.71b	7.80± 0.69b	11.24± 3.17a	0.00
N	11	19	19	19	19	

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

2) Anions in rainwater

2.1) Anions in normal rainwater

Natural rainwater from the open area (sites 1 and 2) had lower concentrations of anions than rainwater from sites 3 and 4. Concentration of Cl^-, NO_3^- SO_4^{2-} and PO_4^{2-} ranged between 0.65-1.11, 0.41-0.94, 0.9-2.05 and 0.18-0.19 ppm, respectively. Rainwater from site 2 had lowest SO_4^{2-} concentrations and was significant higher only in SO_4^{2-} between sites 2 and 3 at the 0.05 level, while Cl^-, NO_3^- and PO_4^{2-} showed no significant in total sites (Table 3.9).

Table 3.9 Anions concentration in normal rainwater (ppm)

Anions	Mean ± S.D. of anions in normal rainwater				
	Site 1	Site 2	Site 3	Site 4	F-value
Cl^-	0.98± 0.79ns	0.65± 0.27ns	0.97± 0.98ns	1.11± 0.83ns	0.600
N	15	10	13	15	
NO_3^-	0.82± 0.60ns	0.75± 0.55ns	0.41± 0.24ns	0.94± 1.62ns	0.595
N	15	10	13	15	
SO_4^{2-}	1.35± 1.32ns	0.90± 0.74ns	2.05± 0.81ns	1.82± 0.71ns	0.071
N	15	10	13	15	
PO_4^{3-}	0.19± 0.01ns	0.19± 0.00ns	0.18± 0.01ns	0.18± 0.01ns	0.747
N	15	10	13	15	

Remark : ns means no significant different at the 0.05 level ($p > 0.05$)

2.2) Anions in simulated rainwater

Concentrations of anions in simulated rainwater and the control treatment were also very different. Cl^-, NO_3^-, SO_4^{2-} and PO_4^{2-} in simulated rainwater ranged between 1.07-71.95, 0.87-42.22, 13.47-2,182.96 and 0.18-0.19 ppm, respectively but the concentrations in control treatment were 1.23, 0.82, 3.08 and 0.19 ppm, respectively. PO_4^{2-} concentration in the normal rainwater and simulated rainwater were not very different (Table 3.10).

The control treatment and the treatments with pH 5.0 had significantly lower Cl^- than pH 4.0, pH 3.0 and pH 2.0. Besides NO_3- concentrations were significant lower in the control treatment, treatment with pH 5.0 and pH 4.0. SO_4^{2-} was significantly higher only at pH 2.0, while in the treatments with pH 3.0 and pH 4.0 had no different, treatment with pH 5.0 and the control treatment also showed no significant differences. There were no significant differences in PO_4^{2-} concentration among sites or among treatments (Table 3.10).

Table 3.10 Concentration of anions in simulated rainwater (ppm)

Anions	Mean ± S.D. of anions in simulated rainwater					
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value
Cl^-	1.23± 0.79d	1.07± 0.87d	26.81± 14.04c	50.27± 26.83b	71.95± 17.56a	0.000
N	11	19	19	19	19	
NO_3^-	0.82± 0.39b	0.87± 0.48b	5.36± 9.62b	42.22± 48.98a	15.35± 46.88ab	0.001
N	11	19	19	19	19	
SO_4^{2-}	3.08± 3.08c	13.47± 12c	202.73± 48.57b	210.35± 168.58b	2182.96 ± 291.43a	0.000
N	11	19	19	19	19	
PO_4^{3-}	0.19± 0.01ns	0.19± 0.01ns	0.19± 0.01ns	0.18± 0.01ns	0.18± 0.01ns	0.198
N	9	21	17	19	19	

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.6 Results of soil analysis

3.6.1 pH of soil

Soil planted with rice, cucumber and tomato showed lower soil pH significantly in pH 2.0 at the 0.05 level. Soil planted with pole bean showed lower soil pH significant differences for control and pH 2.0 treatments at the 0.05 level, while tobacco showed lower soil pH at pH 4.0 and pH 2.0.

However, soil pH did not differ greatly among the control, pH 5.0, pH 4.0 and pH 3.0 treatments except all plant species watered with rainwater at pH 2.0 showed significantly lower at the 0.05 level (p value was 0). Soil pH showed no significant differences between plant species at the 0.05 level and p value was 0.996. (Table 3.11).

3.6.2 Nutrients in soil

1) Sodium in soil (Na^+)

Na^+ concentration in soil treated with pH 5.0, pH 4.0, pH 3.0 and pH 2.0 ranged between 0.06-0.15, 0.05-0.16, 0.04-0.08, and 0.04-0.11 ppm, respectively. Control treatment ranged from 0.07-0.15 ppm. Pole bean, tomato, cucumber, and rice did not great differ Na^+ concentrations among species except tobacco showed lower Na^+ concentration at the 0.05 level (p value was 0.018). All treatment showed no significant differences between treatment at 0.05 level and p value was 0.226 (Table 3.12).

Table 3.11 pH of soil

Soil planted with plants	Mean ± S.D. of soil pH						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	6.58± 0.13a	6.58± 0.08a	6.40± 0.12a	6.47± 0.03a	4.80± 0.36b	0.00	6.16± 0.72ns
N	5	5	5	5	5		25
Cucumber	6.32± 0.24a	6.45± 0.14a	6.27± 0.10a	6.40± 0.08a	5.11± 0.15b	0.00	6.11± 0.53ns
N	5	5	5	5	5		25
Pole bean	6.28± 0.06b	6.48± 0.08a	6.53± 0.10a	6.54± 0.05a	5.19± 0.24b	0.00	6.20± 0.54ns
N	5	5	5	5	5		25
Tomato	6.43± 0.06a	6.45± 0.04a	6.60± 0.13a	6.54± 0.08a	5.03± 0.27b	0.00	6.21± 0.62ns
N	5	5	5	5	5		25
Tobacco	6.59± 0.22a	6.64± 0.09a	6.24± 0.18b	6.61± 0.12a	5.24± 0.34b	0.00	6.26± 0.58ns
N	5	5	5	5	5		25
Treatment mean	6.44± 0.14a	6.44± 0.12a	6.51± 0.08a	6.41± 0.16a	5.07± 0.18b	0.00	6.18± 0.58
N	25	25	25	25	25		125
F-value							0.996

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

Table 3.12 Na^+ concentrations in soil (ppm)

Soil planted with plants	Mean ± S.D. of Na^+ concentrations in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	0.09± 0.02ns	0.10± 0.04ns	0.09± 0.03ns	0.07± 0.03ns	0.07± 0.02ns	0.312	0.08± 0.01ab
N	5	5	5	5	5		25
Cucumber	0.10± 0.05ns	0.06± 0.02ns	0.06± 0.03ns	0.05± 0.04ns	0.07± 0.04ns	0.299	0.07± 0.02ab
N	5	5	5	5	5		
Pole bean	0.15± 0.04a	0.13± 0.02ab	0.11± 0.02ab	0.08± 0.02b	0.11± 0.03ab	0.013	0.11± 0.03a
N	5	5	5	5	5		25
Tomato	0.12± 0.07ns	0.15± 0.18ns	0.16± 0.17ns	0.07± 0ns	0.10± 0.01ns	0.749	0.12± 0.03a
N	5	5	5	5	5		25
Tobacco	0.07± 0.02a	0.07± 0.01a	0.05± 0.02ab	0.04± 0.01b	0.04± 0.01b	0.008	0.05± 0.05b
N	5	5	5	5	5		25
Treatment mean	0.11± 0.03ns	0.10± 0.04ns	0.09± 0.04ns	0.06± 0.02ns	0.08± 0.03ns	0.226	0.09± 0.04
N	25	25	25	25	25		125
F-Value							0.018

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

2) Potassium in soil (K^+)

Soil planted with tomato showed the K^+ concentrations significantly highest among plant species at the 0.05 level (p value was 0.018), while pole bean showed the lowest. There were no significant differences at the 0.05 level among treatments (p value was 0.970).

Only soil planted with pole bean showed the significant differences between treatment at the 0.05 level, while rice, cucumber, tomato and tobacco showed no significant differences at the same level (Table 3.13).

3) Magnesium in soil (Mg^{2+})

Soil planted with tomato showed higher concentrations of Mg^{2+} concentrations than with the other plants at the 0.05 level (p value was 0.012). Treatments means were not significantly different at the 0.05 level (p value was 0.306).

Soil planted with rice, pole bean and tomato, except tobacco and cucumber showed no significant differences between treatments at the 0.05 level. Soil planted with tomato had significantly higher Mg^{2+} concentrations than the other species at the 0.05 level and rice was the lowest (Table 3.14).

Table 3.13 K^+ concentrations in soil (ppm)

Soil planted with plants	Mean ± S.D. of K^+ concentrations in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	0.30± 0.08ns	0.34± 0.07ns	0.31± 0.12ns	0.30± 0.07ns	0.23± 0.16ns	0.617	0.30± 0.10ab
N	5	5	5	5	5		
Cucumber	0.36± 0.20ns	0.44± 0.07ns	0.49± 0.08ns	0.45± 0.09ns	0.48± 0.06ns	0.423	0.40± 0.5ab
N	5	5	5	5	5		
Pole bean	0.09± 0.02b	0.17± 0.03a	0.13± 0.02ab	0.09± 0.02b	0.10± 0.02b	0	0.11± 0.04b
N	5	5	5	5	5		25
Tomato	0.57± 0.26ns	0.58± 0.07ns	0.54± 0.16ns	0.49± 0.12ns	0.53± 0.14ns	0.970	0.54± 0.15a
N	5	5	5	5	5		25
Tobacco	0.33± 0.10ns	0.38± 0.06ns	0.45± 0.09ns	0.32± 0.09ns	0.42± 0.05ns	0.088	0.38± 0.09ab
N	5	5	5	5	5		25
Treatment mean	0.33± 0.18ns	0.38± 0.15ns	0.38± 0.16ns	0.33± 0.16ns	0.35± 0.18ns	0.970	0.58± 0.12
N	25	25	25	25	25		125
F-value							0.018

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

Table 3.14 Mg^{2+} concentrations in soil (ppm)

Soil planted with plants	Mean ± S.D. of Mg^{2+} concentrations in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	0.41± 0.08ns	0.49± 0.08ns	0.34± 0.13ns	0.32± 0.12ns	0.31± 0.17ns	0.128	0.37± 0.13b
N	5	5	5	5	5		25
Cucumber	0.48± 0.23b	0.59± 0.11a	0.54± 0.13ab	0.53± 0.07ab	0.56± 0.02a	0.005	0.54± 0.03ab
N	5	5	5	5	5		25
Pole bean	0.46± 0.04ns	0.45± 0.01ns	0.42± 0.04ns	0.41± 0.02ns	0.43± 0.04ns	0.123	0.43± 0.04ab
N	5	5	5	5	5		25
Tomato	0.55± 0.09ns	0.60± 0.04ns	0.61± 0.10ns	0.58± 0.06ns	0.54± 0.07ns	0.533	0.58± 0.07a
N	5	5	5	5	5		25
Tobacco	0.40± 0.08b	0.62± 0.08a	0.51± 0.02ab	0.36± 0.11b	0.46± 0.02ab	0	0.47± 0.11ab
N	5	5	5	5	5		25
Treatment mean	0.46± 0.05ns	0.55± 0.07ns	0.48± 0.11ns	0.44± 0.11ns	0.46± 0.09ns	0.306	0.47± 0.07
N	25	25	25	25	25		225
F-Value							0.001

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

4) Calcium in soil (Ca^{2+})

Soil planted with cucumber treated with pH 5.0 and pH 4.0 showed higher Ca^{2+} concentrations than the other treatments at the 0.05 level, while pole bean and tobacco treated with pH 5.0 showed higher Ca^{2+} concentrations than the other treatments. Rice and tomato showed no significant difference between treatments at the 0.05 level (p value more than 0.05).

Soil treated with pH 5.0 showed significantly highest Ca^{2+} concentrations among treatments at the 0.05 level, while the control treatment showed the lowest. Treatments means showed significantly differences at the 0.05 level and p value was 0.023 (Table 3.15).

5) Phosphate in soil (PO_4^{2-})

PO_4^{2-} concentrations in soil planted with tobacco treated with pH 5.0 and pH 4.0 was higher significant differences at the 0.05 level, and also showed significant differences between treatment at p value less than 0.05 level. Soil planted with rice, cucumber, pole bean and tomato showed no significant differences between treatment at the 0.05 level ($p > 0.05$).

Treatment means showed no significant differences at p more than 0.05 level. Moreover, the comparison between plant species showed no significant differences at the 0.05 level and p value was 0.076 (Table 3.16).

Table 3.15 Ca^{2+} concentrations in soil (ppm)

Soil planted with plants	Mean ± S.D. of Ca^{2+} concentrations in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	4.54± 0.86ns	6.17± 1.65ns	4.38± 1.20ns	3.73± 1.19ns	3.30± 2.71ns	0.105	6.17± 1.65ns
N	5	5	5	5	5		
Cucumber	2.81± 2.58b	7.26± 1.55a	6.42± 0.49a	5.80± 0.58ab	5.74± 0.38ab	0.001	5.60± 2.00ns
N	5	5	5	5	5		
Pole bean	5.21± 0.39b	6.79± 0.72a	5.27± 0.41b	4.91± 0.20b	5.07± 0.37b	0	5.45± 0.81ns
N	5	5	5	5	5		25
Tomato	6.06± 0.91ns	6.99± 0.21ns	6.94± 1.13ns	6.57± 0.63ns	6.31± 1.28ns	0.454	6.57± 0.91ns
N	5	5	5	5	5		25
Tobacco	4.44± 0.78b	7.03± 1.04a	5.45± 0.28ab	4.29± 1.26b	5.06± 0.36b	0	5.25± 1.26ns
N	5	5	5	5	5		25
Treatment mean	4.61± 1.19b	6.84± 0.41a	5.69± 1.00ab	5.06± 1.14ab	5.09± 1.13ab	0.023	5.46± 1.22
N	25	25	25	25	25		125
F-value							0.076

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

Table 3.16 PO_4^{2-} concentrations in soil (ppm)

Soil planted with plants	Mean ± S.D. of PO_4^{3-} concentrations in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-Value	Species mean
Rice	15.07± 0.39ns	15.65± 0.79ns	14.94± 0.63ns	13.77± 1.86ns	14.84± 1.21ns	0.150	14.85± 1.19ns
N	5	5	5	5	5		25
Cucumber	14.45± 1.67ns	16.72± 1.85ns	14.44± 1.65ns	16.04± 2.53ns	17.14± 1.41ns	0.094	15.76± 2.05ns
N	5	5	5	5	5		25
Pole bean	14.95± 0.16ns	15.23± 0.28ns	14.72± 0.46ns	14.25± 1.02ns	14.18± 0.78ns	0.070	14.66± 0.70ns
N	5	5	5	5	5		25
Tomato	15.14± 0.56ab	16.31± 0.56a	16.39± 0.48a	13.44± 1.26b	13.81± 2.07b	0.001	15.02± 1.64ns
N	5	5	5	5	5		25
Tobacco	15.14± 0.56ab	16.31± 0.65a	16.39± 0.48a	13.44± 1.26b	13.81± 2.07b	0.001	15.02± 1.64ns
N	5	5	5	5	5		25
Treatment mean	14.81± 0.33ns	16.12± 0.66ns	14.98± 0.81ns	14.70± 1.24ns	15.68± 1.37ns	0.129	15.26± 1.04
N	25	25	25	25	25		125
F-value							0.359

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

6) Sulfate in soil (SO_4^{2-})

All of the pH 2.0 treatments resulted in the high concentrations of SO_4^{2-}, ranging between 6.14-23.37 ppm, especially soil planted with pole bean and tomato with SO_4^{2-} at 23.37 and 14.66 ppm, respectively. All the control, pH 5.0 and pH 4.0 treatments were not showed significantly differences at the 0.05 level

Soil grown with total plant species were higher significant different in pH 2.0 at the 0.05 level. Soils treated with pH 2.0 showed significantly higher SO_4^{2-} levels than the other treatments at p value less than 0.05 level. Treatment means showed significantly differences among treatments at p value 0.001 (Table 3.17).

3.6.3 Nitrogen in soil

Highest percent nitrogen was found in soil planted with tomato, treated with pH 3.0 (0.28 percent), while the lowest percent nitrogen was 0.14 and found in soil planted with rice at pH 3.0 and soil planted tobacco at pH 2.0.

Only soil planted with pole bean showed no significant differences among treatments at the 0.05 level (p value was 0.156), and the other soils showed significant different between treatment at p value less than 0.05 level.

There were no significant differences in total nitrogen in soil among species means and among different treatments means at the 0.05 level (Table 3.18).

Table 3.17 SO_4^{2-} concentrations in soil (ppm)

Soil planted with plants	Mean ± S.D. of SO_4^{2-} concentrations in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	0.31± 0.13c	0.68± 0.01bc	1.23± 0.09bc	2.83± 1.07b	6.37± 1.16a	0	2.15± 2.50ns
N	5	5	5	5	5		25
Cucumber	0.47± 0.14b	0.67± 0.03b	0.75± 0.02ab	2.34± 1.11ab	6.48± 2.30a	0.011	2.53± 2.84ns
N	5	5	5	5	5		25
Pole bean	0.34± 0.49c	2.08± 0.25c	3.77± 0.72bc	11.94± 2.89b	23.37± 4.76a	0	8.25± 8.49ns
N	5	5	5	5	5		25
Tomato	0.32± 0.05c	0.58± 0.16c	1.94± 1.51c	8.97± 0.19b	14.66± 3.76a	0	4.01± 5.53ns
N	5	5	5	5	5		25
Tobacco	0.60± 0.41c	1.93± 0.55bc	3.21± 0.83b	5.19± 0.14a	6.14± 0.66a	0	3.13± 2.12ns
N	5	5	5	5	5		25
Treatment mean	0.41± 1.25b	1.18± 0.75b	2.18± 1.28b	6.25± 4.11ab	11.40± 7.6a	0.001	4.28± 5.49
N	25	25	25	25	25		125
F-value							0.377

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

Table 3.18 Percent nitrogen in soil

Soil planted with plants	Mean ± S.D. of percent nitrogen in soils						
	Control	pH 5.0	pH 4.0	pH 3.0	pH 2.0	F-value	Species mean
Rice	0.21± 0.06a	0.25± 0.01a	0.17± 0.05b	0.14± 0.05b	0.25± 0.01a	0.014	0.20± 0.05ns
N	5	5	5	5	5		25
Cucumber	0.18± 0.07b	0.25± 0a	0.17± 0.06b	0.23± 0.06a	0.21± 0.01a	0.030	0.21± 0.03ns
N	5	5	5	5	5		25
Pole bean	0.21± 0.05ns	0.22± 0.06ns	0.16± 0.06ns	0.19± 0.01ns	0.24± 0.05ns	0.156	0.20± 0.03ns
N	5	5	5	5	5		25
Tomato	0.19± 0.03b	0.21± 0.02ab	0.23± 0ab	0.28± 0.03a	0.20± 0.03b	0.000	0.22± 0.03ns
N	5	5	5	5	5		25
Tobacco	0.16± 0.05b	0.20± 0.02ab	0.26± 0.01a	0.21± 0.03ab	0.14± 0.03b	0.000	0.19± 0.05ns
N	5	5	5	5	5		25
Treatment mean	0.18± 0.02ns	0.23± 0.02ns	0.20± 0.04ns	0.21± 0.05ns	0.21± 0.04ns	0.626	0.20± 0.04
N	25	25	25	25	25		125
F-value							0.827

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.7 Plant analysis

Only pole bean and tomato plants were analysed for chemical constituents and only for the control treatment, pH 5.0, pH 3.0 and pH 2.0. Sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), phosphorus (P), total sulfur (S), and total nitrogen were analysed.

3.7.1 Nutrients in plants

1) Na^+

Pole bean plants treated with pH 3.0 had the highest concentration of Na^+ and the lowest was with the pH 5.0 treatments. Tomato with the control and pH 3.0 were not significant different concentrations of Na^+ and higher than the other. While the treatment with pH 5.0 and 2.0 had the lowest Na^+ concentrations. Pole bean had Na^+ concentrations significantly lower than tomato at the 0.05 level (Table 3.19).

2) K^+

Pole bean had highest concentrations of K^+ in treatment with pH 5.0 and lowest at pH 3.0, while tomato had highest K^+ concentrations at pH 2.0 and lowest at pH 3.0. However, K^+ concentrations in pole bean was significantly lower than in tomato plants in treatment with pH 2.0. There were no significant differences among treatments means at the 0.05 level and p value was 0.358 (Table 3.20).

Table 3.19 Na^+ concentrations in plant tissues (ppm)

Plants	Mean ± S.D. Na^+ concentrations in plants tissues					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	0.32± 0.07b	0.28± 0.07c	0.41± 0.09a	0.34± 0.07b	0.020	0.34± 0.01b
N	3	3	3	3		12
Tomato	0.88± 0.06a	0.66± 0.15b	0.82± 0.09a	0.66± 0.02b	0.001	0.76± 0.11a
N	3	3	3	2		11
Treatment mean	0.60± 0.31ns	0.50± 0.22ns	0.62± 0.29ns	0.47± 0.27ns	0.214	0.55± 0.29
N	6	6	6	5		23
F-value						0.000

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

Table 3.20 K^+ concentrations in plant tissues (ppm)

Plants	Mean ± S.D. of K^+ concentrations in plant tissues					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	17.72± 6.25a	17.98± 1.93a	16.28± 3.52b	17.13± 5.75a	0.00	17.28± 0.75ns
N	3	3	3	3		12
Tomato	19.37± 1.81b	19.24± 3.18b	17.72± 0.13b	29.22± 0.59a	0.004	21.39± 5.27ns
N	3	3	3	2		11
Treatment mean	18.55± 1.16ns	18.61± 0.89ns	17.00± 1.02ns	23.18± 8.55ns	0.358	19.33± 2.91
N	6	6	6	5		23
F-value						0.074

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3) Mg^{2+}

Pole bean plants had highest concentrations of Mg^{2+} in treatments with pH 5.0 and pH 3.0 and there were significant differences in Mg^{2+} concentrations among the treatments at the 0.05 level. Tomato plants had highest concentrations of Mg^{2+} with pH 3.0 and pH 5.0, while the control and treatment with pH 2.0 resulted in the lowest and there were significant differences among treatments at p less than 0.05 level.

Pole bean plants had significantly higher concentrations of Mg^{2+} than tomato plants. The lowest treatment means was with the control but there were no significant differences among treatments at p more than 0.05 level (Table 3.21).

Table 3.21 Mg^{2+} concentrations in plants tissues (ppm)

Plants	Mean ± S.D. of Mg^{2+} concentrations in plant tissues					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	7.24± 1.40b	8.62± 0.40a	8.83± 1.59a	7.90± 0.87ab	0.00	8.15± 0.73a
N	3	3	3	3		12
Tomato	4.12± 0.88ab	5.07± 0.55a	5.91± 0.52a	3.39± 0.41b	0.004	4.62± 0.21b
N	3	3	3	2		11
Treatment mean	5.68± 2.20ns	6.85± 2.51ns	7.37± 2.06ns	5.65± 3.19ns	0.531	6.38± 2.49
N	6	6	6	5		
F-Value						0.000

Remark 1.ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

4) Ca^{2+}

Pole bean plants had highest concentrations of Ca^{2+} in treatments with normal rainwater and lowest at pH 2.0. Tomato plants had highest Ca^{2+} concentrations at normal rainwater and pH 3.0, while pH 2.0 had the lowest concentration of Ca^{2+}.

A comparison between pole bean and tomato showed no significant differences in Ca^{2+} concentrations, but both pole bean and tomato had different mean of Ca^{2+} concentrations between the treatments using normal rainwater and pH 2.0. The differences were significant at the 0.05 level (Table 3.22).

Table 3.22 Ca^{2+} concentrations in plant tissues (ppm)

Plants	Mean ± S.D. of Ca^{+} concentrations in plants tissues					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	24.36± 6.42a	21.24± 1.82ab	18.09± 1.84b	12.89± 1.12c	0.004	19.14± 4.89ns
N	3	3	3	3		12
Tomato	19.87± 1.65a	15.40± 2.70b	18.02± 4.49a	14.60± 6.45b	0.001	16.97± 2.42ns
N	3	3	3	2		11
Treatment mean	22.11± 4.86ns	18.32± 3.80ns	18.06± 3.07ns	16.66± 4.90ns	0.186	18.88± 4.41
N	6	6	6	5		23
F-value						0.330

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

5) Phosphorus

Pole bean and tomato plants treated with pH 3.0 resulted in the highest phosphorus concentration in their tissues and there were no significant different between treatments at the 0.05 level.

There were significant differences in phosphorus concentrations between pole bean and tomato at the 0.05 level (p value was 0.001). Treatments means of simulated rainwater (pH 5.0, pH 3.0 and pH 2.0) and control treatment showed no significant differences at the 0.05 level (Table 3.23).

Table 3.23 Phosphorus concentrations in plant tissues (ppm)

Plants	Mean ± S.D. of phosphorus concentrations in plant tissues					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	0.22± 0.02ns	0.23± 0ns	0.25± 0.06ns	0.23± 0.02ns	0.778	0.23± 0.03b
N	3	3	3	3		12
Tomato	0.38± 0.15ns	0.34± 0.06ns	0.43± 0.09ns	0.25± 0.01ns	0.296	0.36± 0.11a
N	3	3	3	2		11
Treatment mean	0.3± 0.13ns	0.29± 0.07ns	0.34± 0.12ns	0.23± 0.02ns	0.373	0.29± 0.1
N	6	6	6	5		23
F-value						0.001

Remark : ns means no significant different at the 0.05 level ($p > 0.05$)

6) Sulfur

Highest concentrations of sulfur were found in pole bean and tomato plants treated with pH 2.0 and lowest with control treatment. Tomato plants had significantly higher concentrations of sulfur than pole bean plants.

However, the mean of pole bean and tomato plant from all treatments had no significant differences among species at the 0.05 level. Treatment means showed significantly higher sulfur concentrations in pH 2.0 than the control treatment at the 0.05 level (Table 3.24).

Table 3.24 Sulfur concentrations in plant tissues (ppm)

Plants	Mean + S.D. of sulfur concentrations in plant tissues					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	63.56± 10.06d	87.62± 4.79c	104.55± 4.71b	145.24± 2.79a	0.000	100.24± 31.56ns
N	3	3	3	3		12
Tomato	72.85± 3.72d	93.59± 2.49c	118.82± 3.19b	195.06± 6.82a	0.000	113.26± 44.32ns
N	3	3	3	2		11
Treatment mean	68.2± 8.48d	90.61± 4.73c	111.69± 8.6b	165.17± 27.57a	0.000	106.47± 37.88
N	6	6	6	5		23
F-value						0.423

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)

3.7.2 Nitrogen in plants

Both pole bean and tomato, treated with pH 5.0, had the highest percent nitrogen. While pole bean had higher concentrations of nitrogen than tomato but not significantly higher at the 0.05 level.

However, there were significantly higher concentrations of nitrogen in plants treated with pH 5.0 than in control, pH 3.0 and pH 2.0 treatments at the 0.05 level (Table 3.25).

Table 3.25 Percent nitrogen in plant tissues

Soil planted with plants	**Mean ± S.D. of percent nitrogen in plant tissues**					
	Control	pH 5.0	pH 3.0	pH 2.0	F-value	Species mean
Pole bean	0.75± 0.06b	1.00± 0.03a	0.87± 0.03b	0.77± 0.17b	.044	0.85± 0.06ns
N	3	3	3	3		12
Tomato	0.57± 0.04ns	0.88± 0.21ns	0.68± 0.07ns	0.74± 0.09ns	0.093	0.72± 0.09ns
N	3	3	3	2		11
Treatment mean	0.66± 0.1b	0.94± 0.15a	0.78± 0.12b	0.76± 0.13b	0.010	0.78± 0.16
N	6	6	6	5		23
F-value						0.050

Remark 1. ns means no significant different at the 0.05 level ($p > 0.05$)

2. Mean values not sharing the same letters are significantly different ($p < 0.05$)